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DETECTION OF VENUS' ROTATION PERIOD AND OF THE FUNDAMENTAL PHYSICAL FEATURES OF THE PLANET'S SURFACE.

PERCIVAL LOWELL.

FOR POPULAR ASTRONOMY.

Owing hitherto to the impossibility of making out any certain markings upon the disk of the planet, the rotation period of Venus, together with the determination of all its dependent phenomena, has up to the present time been a matter of doubt. The history of the subject was thus summed up by Stanley Williams in the last edition of Webb, published in 1893.

"The question of the duration of the rotation of Venus is still a disputed one, and several very elaborate though contradictory investigations upon the subject have been published within the last few years. In 1890 Schiaparelli came to the conclusion after a very exhaustive discussion of all the existing material, including some observations of his own, that the rotation of Venus is very slow; and that whilst being very probably equal to the time taken by the planet in making one revolution round the Sun (225 days), it is certainly not less than 6 months or greater than nine months. Perrotin confirms this slow rotation from observations of the markings on the disc made by him at Nice in 1890, and fixes it at from 195 to 225 days. In the same year Terby published a number of observations made by him in 1887-89, which appeared to him to still further confirm the slow duration of the rotation. But in 1891 appeared an important memoir by Niesten, giving the results of many observations made by himself and Stuyvaert at Brussels between 1881 and 1890. These observers, instead of supporting the slow rotation, strongly confirm the short rotation period of De-Vico. They also found the markings so evident and apparently permanent, that they were able to construct a map of them. This map, however, does not bear the slightest resemblance to that of Bianchini on p. 58. More recently still Trouvelot has discussed the subject, and decides that the rotation is performed in about 24 hours. His observations of a large dark spot are referred to on p. 61. With results so contradictory, and obtained too by some of our very best ob-

servers, it is difficult to come to a satisfactory conclusion upon the subject. The balance of the evidence appears at present, however, to be in favor of a rotation in about 24 hours."

Since this Leo Brenner has published several papers affirming strongly the rotation period of about 24 hours.

Such was the state of our knowledge when in August I began systematic observations upon the planet with the 24 inch refractor. I had no sooner begun observing than it was apparent that there were markings upon the disk and before long it was furthermore apparent that the markings bore no resemblance to the indefinite patches commonly depicted. So distinct and definite did the markings prove that they have resulted in the detection of the planet's rotation and of the fundamental physical characteristics of the planet's surface. I shall give in this paper a first summary of what they have disclosed, together with reproductions of some of my drawings and those of my assistant Mr. Drew.

To begin with, then, the markings are both distinct and well defined; their contours standing out sharply against the lighter parts of the disk. In shape they are of two kinds: long, relatively narrow, and, generally speaking, straight markings; and spots. They are all of them permanent and permanently visible, our own air alone ever obscuring them. Indeed the seeing must be distinctly bad to have the more prominent among them not discernible. Such phenomena show that they belong to the actual surface of the planet itself.

As the rotation period is of primary importance both to the planet's past and present history we may take up its determination first.

The markings disclose the rotation period unmistakably. This period proves to be identical with the planet's orbital period. Such will be evident on comparing the several drawings with one another. In the first place the markings show at once that any rotation period of about 24 hours is impossible. The five drawings of October 15th furnish the most forthright evidence of this. For they cover between them a period of about five hours and during all this time the markings show no change. But in an interval of five hours the planet would, on the supposition of a rotation period of about 24 hours, have rotated through 75 degrees which would have caused the central markings to travel about five-eighths of their apparent journey across the disk.

So much for the negativing any short rotation period. The ac-

PLATE XXIV.

Aug. 24 5^h 40^m
$\lambda = 18°$

Aug. 31 2^h 48^m 52^s
$\lambda = 21°$

Aug. 31 5^h 35^m
$\lambda = 21°$

Sept. 29 3^h 30^m
$\lambda = 31°$

Sept. 29 5^h 12^m
$\lambda = 31°$

Oct. 4 4^h 5^m
$\lambda = 32°$

Oct. 9 1^h 19^m — 2^h 28^m
$\lambda = 35°$

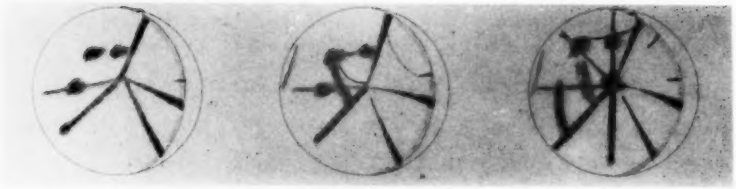
Oct. 9 2^h 48^m — 56^m
$\lambda = 35°$

Oct. 9 5^h 3^m — 8^m
$\lambda = 35°$

VENUS.

Drawn by Percival Lowell, Lowell Observatory.

PLATE XXV.



Oct. 13 $2^h\ 55^m - 3^h\ 4^m$
$\lambda = 37°$

Oct. 14 $1^h\ 59^m - 2^h\ 12^m$
$\lambda = 37°$

Oct. 14 $3^h\ 13^m$ to 18^m
$\lambda = 37°$

Oct. 14 $3^h\ 50^m$
$\lambda = 37°$

Oct. 15 $0^h\ 5^m$ to 14^m
$\lambda = 37°$

Oct. 15 1^h
$\lambda = 37°$

Oct. 15 $2^h\ 10^m$ to 21^m
$\lambda = 37°$

Oct. 15 $3^h\ 48^m$ to 55^m
$\lambda = 37°$

Oct. 15 $4^h\ 57^m$
$\lambda = 37°$

VENUS.

Drawn by Percival Lowell, Lowell Observatory, Oct. 16, 1896.

tual rotation period is disclosed by a certain detail of their presentation of an instantly tell-tale character. This feature is the fact that the markings always hold the same position with regard to the terminator. For such a relation to the terminator shows that the rotation period and the orbital one coincide and that the axis of rotation is perpendicular to the plane of the orbit. This will at once be evident on considering what must occur in the case of a body travelling in an orbit practically circular, and rotating about such an axis once in the course of its circuit of the Sun: its illuminated side must remain forever the same. In whatever position, therefore, the body be presented to the view of an outsider, the boundary of the light and shade must occupy perpetually the same points upon the body's surface. In an orbit non-circular, in consequence of the eccentricity of that orbit, there would take place a certain libration in longitude and in consequence of any tilt in the axis there would occur one in latitude. But the orbit of Venus is practically circular, its eccentricity being only .00684 and the consequent libration from apse to apse amounts, therefore, at most to 47′, a quantity smaller than the inevitable errors of observation.

As the next point: the successive positions of the markings show that the axis of rotation is practically perpendicular to the plane of the orbit. This is disclosed by the fact that the markings in the course of their apparent journey in company with the terminator traverse the disc in straight lines. As yet no deviation from this course has been revealed by the drawings down to the last yet made, those of November 9; any apparent slight variations which may appear in any single drawing being shown by a comparison of all to be within the errors of observation.

Besides giving the period of the rotation and the position of the axis of that rotation, the markings establish certain physical characteristics with regard to the surface condition of the planet of which the chief are the following:

First, the invariable visibility of the markings shows that they are not obscured at any time by clouds. In other words there are no clouds upon the planet.

Next: the intense lustre of the disk is shared by all the markings. It is as if a bright veil of some sort were drawn over the whole disk, making the bright parts brighter and the dark less dark. Compared with Mercury and his markings the effect is striking. The bright parts of Mercury are very much fainter than are those of Venus, while his dark markings are very much darker than hers. This veil is unquestionably atmosphere.

The presence of atmosphere is further corroborated by the relative measures I have made of the planet's polar and equatorial diameters as compared with those of Mercury. The Venusian appears to reveal a twilight arc as the Martian ones do—while the Mercurial do not.

Third: there appears to be no sign of water or of vegetation upon the planet. This is shown by the absence of color in any part of the disk. The disk is simply a design in black and white over which is drawn a brilliant straw-color veil. Compared with the pronounced and beautiful tints of Mars, the white, blue-green and reddish-yellow, Venus is a very drab-like thing.

Such appearance is what the probable meteorologic conditions prevailing on the sun-lit side of the planet would lead us to infer a priori. Being exposed in perpetuity to the full blaze of the Venusian sun, it would seem that a funnel-like indraught of air from the dark side to the bright and then an umbrella-like return of it, would necessarily result and that the eventual outcome of this would be the depositing of almost all the water upon the unilluminated side where in the form of ice it would substantially remain.

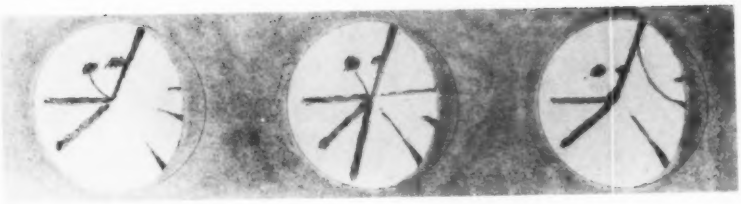
Furthermore there is no evidence of any polar-caps. At one time I thought to see something of the kind but it had nothing of the unmistakableness of the Martian polar caps and the effect has not been repeated. It was undoubtedly of simple irradiation origin.

The absence of polar caps tallies with the above meteorological view since on that supposition there should be, not polar caps, but a polar hemisphere which the absence of sensible libration would forever hide from our view. Mr. Godfrey Sykes suggests that such an ice-clad hemisphere may account for the phosphorescence seen upon the dark side.

We may now consider the markings in detail. So permanently visible are they that I have been able to construct the accompanying map of the only hemisphere Venus can ever show us. The relative absence of markings on the left side of the map simply means that during the observations that side was not favorably presented, the extreme edge not having heen presented at all, as the observations began when the phase angle was 17°.

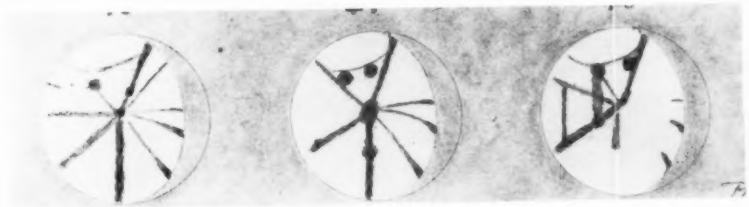
The most instantly curious phenomenon about the markings is that a great many of them are of the general nature of broadish lines radiating from a certain point in longitude 37° and north latitude 8°. Curious as this character and distribution appears to be, the look of the whole is natural. There is nothing about

PLATE XXVI.



Oct. 16 0^h 15^m to 25^m Oct. 16 5^h to 5^h 5^m Oct. 17 3^h 30^m

Oct. 19 3^h 25^m to 34^m Oct. 19 5^h 5^m Oct. 20 1^h



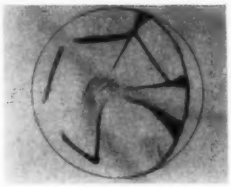
Oct. 23 23^h 36^m — 43^m Oct. 25 3^h 45^m Oct. 25 4^h 2^m — 11^m

VENUS.

Drawn by Percival Lowell, Lowell Observatory, Oct., 1896.

PLATE XXVII.

Sept. 29 $4^h\ 10^m$



Oct. 7 $5^h\ 5^m$

Oct. 8 $3^h\ 15^m$

Oct. 8 5^h

Oct 9 $2^h\ 40^m$

VENUS.

Drawn by D. A. Drew, Lowell Observatory.

the system bearing resemblance to the noticeable artificiality of the markings of Mars.

The next most salient features are the spots. Chief among these are two *oculi* in longitudes 8° and 38° and latitudes 36° and 38° north.

Another feature worth mentioning is the permanent projection about 20° to the west of the southern cusp. This would seem to have been seen by Schröter. That from observations of the return of this projection he deduced a rotation period of 23 hours 21 minutes 19 seconds is worth quoting since the projection was never absent.

Lastly: the relative visibility of some of the markings changes with their position with regard to the observer. For instance Somnus regio, which was almost invisible when in the centre of the disk, has grown more conspicuous as it has approached the limb. Anteros regio and Adonis regio have similarly become less salient on nearing the central meridian. Other markings under like conditions of position and illumination have not done so, but have remained as evident in the one aspect as in the other or, as in Hermione regio, have become less conspicuous on nearing the limb. As of two markings occupying the same part of the disk, Hermione regio and Somnus regio for example, the one will change in one way, the other in the opposite manner, the change cannot be a matter of obscuration. Secondly as the position of the markings has not shifted with regard to the Sun, the change cannot be intrinsic. It is therefore probably due to a difference in the character of the rock or soil, greater or less roughness for example, in one region than in the other which causes them to appear differently under different angles of illumination. That in these markings we are looking down on a bare desert-like surface is what the observations imply.

INDEX TO MAP OF VENUS.

a	Eros	*l*	Dione regio
b	Psyche regio	*m*	Paris regio
c	Hermione regio	*n*	Hymenæus regio
d	Astoreth	*o*	Hyphæstos regio
e	Ashera	*p*	Istar
f	Anchises regio	*q*	Somnus regio
g	Hero regio	*r*	Cytherea regio
h	Aphrodite regio	*s*	Cypria regio
i	Aeneas regio	*t*	Pothos
j	Anteros regio	*u*	Bilit
k	Adonis regio	*v*	Astarte regio
		w	Libentina Regio

LOWELL OBSERVATORY, November, 1896.

THE ORBIT OF CASTOR.

S. W. BURNHAM.

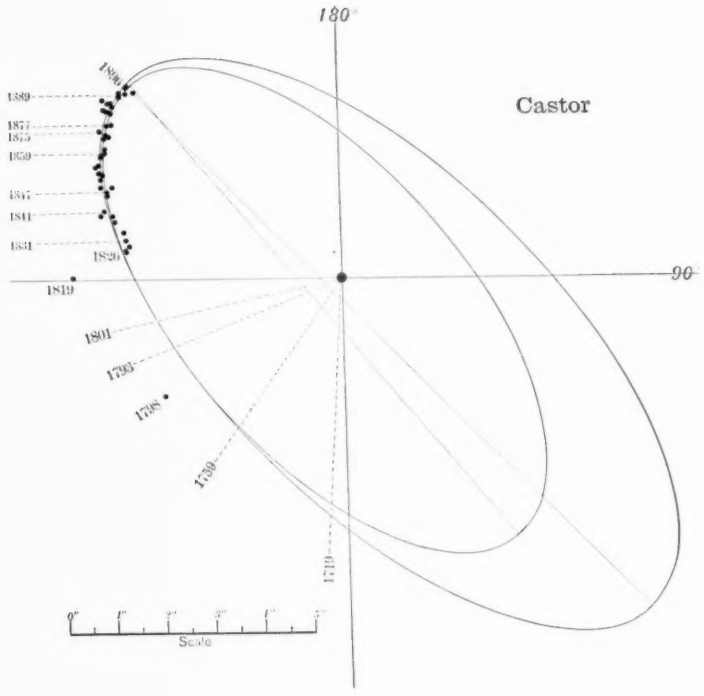
FOR POPULAR ASTRONOMY.

The most brilliant as well as the best known double star in the heavens is the bright star Castor. It is at all times a wide pair, and the brightness and equality in magnitude of the components renders it an easy object with even the smallest instruments, and consequently there are probably more measures of it than any other pair known. Indeed, a great amount of time has been practically wasted by many observers in duplicating over and over again measures of this and similar pairs, since they contribute nothing to the determination of the relative position and motion of the two stars. Very many of them have large errors for so easy a pair, and in fact materially increase the difficulty of arriving at any correct conclusion.

Mr. Lewis, in his interesting history of double star astronomy, mentions many earlier observations of bright double stars like Castor, γ Virginis, ζ Ursæ Majoris, etc., by Bradley, Mayer and others at various times preceding the work of Sir William Herschel, but gives the year 1779, as the true beginning of double star astronomy, and this is undoubtedly correct. These stars were incidentally noted by the early astronomers with small and inferior instruments, but it remained for Herschel with his more powerful reflectors to recognize the importance of these stellar systems, and take hold of the work in an earnest and systematic way.

The observations of Castor, so far as any record of the position angle is concerned, seem to commence with Bradley and Pound in 1719, who estimated the line joining the two components to be parallel with that between the naked eye stars κ and σ. In 1759 it was again observed by Bradley and Maskelyne and estimated to be parallel to the line joining Castor and Pollux. The angles derived from this early records have been used by Herschel and others to represent the approximate positions of the stars at those times. The observations of Herschel I commence in 1778 (Phil. Trans. 1782) and are repeated at intervals up to 1803. They are for the most part confined to the measure of the position-angle, but on three occasions he attempted the distance. He refers to Mayer's memoir on double stars, in which the difference of R. A. and Decl. of the components of Castor is given, and says these quantities reduced to the usual notation give 293°.2 for the

PLATE XXVIII.



position angle, and 9″.63 for the distance "center to center," and gives his own angle for 1779 as 302°.8, and the distance 5″.15, "diameters included." His latest measure in 1779 "with my last new micrometer" gives 4″.34 for the distance "from center to center." This distance is shown on the accompanying diagram. The complete measures by Struve of angle and distance commence in 1819, and are continued at short intervals to 1838; but accurate and reliable measures of this pair begin with the systematic observations of Struve in 1826. His distance in 1819 is obviously too large, and also the distance of Herschel and South in 1822. From 1826 to 1874 we have a continuous series of careful and reliable measures at Dorpat and Pulkowa by the two Struves.

Many attempts have been made by computers in the last 60 years to find the period and other elements of the orbit of this system. The first was by Herschel in 1831. He had the early observations to work with, and the first set of measures by Struve in 1826; and the comparison of the observed and computed positions, as might be expected from so small an arc, was entirely satisfactory; but he says, "nevertheless it must be confessed that the data are after all too uncertain to warrant perfect confidence in its correctness." A little later other astronomers, with practically the same data so far as this problem was concerned, endeavored to arrive at some better result, and found periods covering a wide range of time, and orbits which had very little similarity between them. For example, Madler in 1841, made the periodic time 232 years, while Hind with additional measures of only four years found 632 years, and Thiele in 1859 with but a trifling increase in the position angle concluded that the companion star would require 996 years to make one revolution. The later investigations are equally uncertain and inconsistent.

The following is a list of the various orbits, arranged in chronological order, with the periods and the dates of the last measures used in the respective computations:

1831	Herschel II	252.66 years	Mem. R. A. S. Vol. V.
1841	Madler,	232.12 "	A. N. 452: Dorp Obsns. IX.
1845	Hind,	632.27 "	A. N. 551.
1846	Jacob,	653.1 "	Mem. R. A. S. Vol. XVI.
1847	Madler,	519 77 "	Fixst. System.
1859	Thiele,	996.85 "	A. N. 1227.
1875	Wilson,	982.9 "	Handbook of Double Stars.
1877	Doberck,	1001.21 "	A. N. 2168.
1878	Thiele,	720 "	"Castor," Copenhagen, 1879.
1889	Mann	265.7 "	Sid. Mess. IX 385.

On the accompanying diagram I have given the early positions,

and then the measures of the best observers who have made regular observations. Each position is the mean of several nights' measures, never less than three, and usually more. Altogether 49 positions of the companion are shown by the following observers:

1719, 1759	Bradley	2
1779, 1793, 1801	Herschel I	3
1819 to 1838	Struve	8
1840 to 1874	O. Struve	22
1877	Dembowski	1
1878 to 1891	Hall	11
1894	Bigourdan	1
1896	Comstock	1

The dates of the last measures used in the several orbits are indicated on the diagram, so that the respective arcs made use of in the computations can be seen at once.

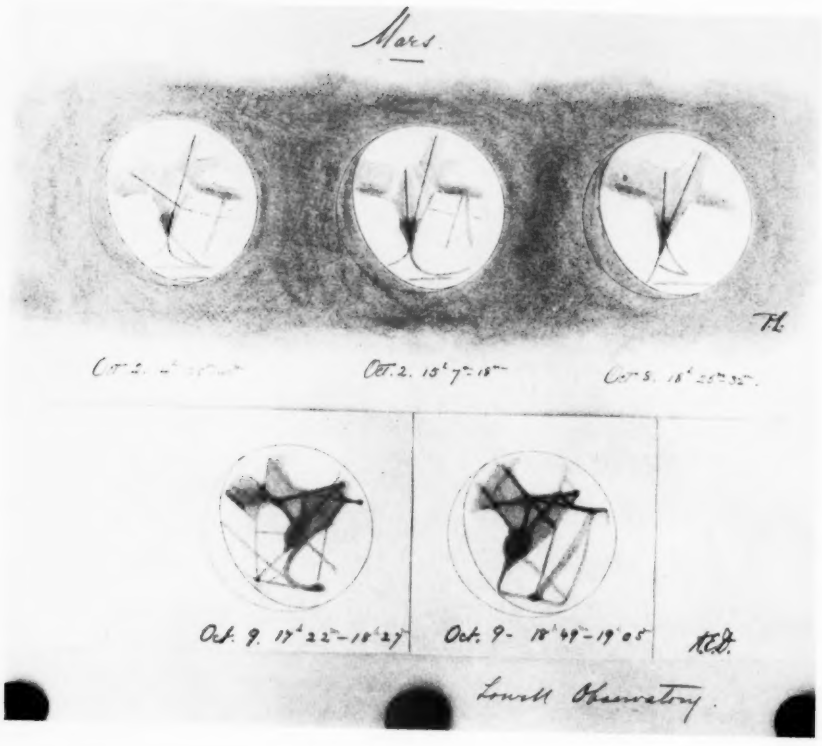
I have endeavored to find the smallest ellipse which will satisfy all the positions from 1719 to 1895, and that given on the diagram is the one selected after many trials. It is based upon the area described during the interval of 69.6 years covered by the complete measures from 1826 to 1895. The ellipse is drawn to represent the early angles with this rate of motion. The general errors of the complete positions are sufficiently shown on the diagram. The errors of the angles in the first century of observation are:

	°		°
1719.8	+ 1.5	1793.1	0.0
1759.8	+ 1.7	1801.8	0.0
1779.8	+ 1.5	1819.8	− 1.8

Certainly no better representation of these observations could be asked for, even if they had been made by the most experienced modern observers with the best modern refractors. It might be objected that the agreement of the earlier crude observations with the theory is altogether too perfect to make it probable that the ellipse shown is likely to be the correct apparent orbit. It would be extraordinary, to say the least, if these estimated and roughly measured angles were affected by errors as small as those given. This ellipse gives a period of 456.8 years. For obvious reasons I have not thought it worth while to deduce the other elements of the real orbit.

It is evident from an inspection of the diagram that this is not the only ellipse which can be found to represent all the observations; and that a variety of figures giving much longer periodic times will satisfy the conditions practically as well as the one

PLATE XXIX.


Mars.
Oct. 2. 15h 7m-15m
Oct. 9. 17h 22m-18h 27m
Oct. 9- 18h 49m-19h 05m
Lowell Observatory.

referred to. As a further illustration of the uncertainty which exists even now with reference to the future path of the companion star, although the range is much less than it was thirty years ago, I have given another ellipse, which, so far as all the observations are concerned, is practically identical with the smaller figure, and equally well represents those positions. This ellipse gives a period of 656.7 years. For anything that appears, a larger apparent orbit, giving a much longer period, is equally probable. With the latitude that is certainly allowable in respect to the probable errors of the earlier positions, a great variety of entirely dissimilar figures could be shown; and if the maximum distance between the two stars has not been reached, and it is by no means certain that it has, an almost infinite variety of orbits could be still found. It will certainly require the observations of another half century, and probably for a very much longer time, to determine the elements of this system even to a rough approximation. Many computers seem to have fallen into the singular error of assuming that because an orbit represents all the measures in an entirely satitfactory manner, it must necessarily be at least approximately correct, entirely overlooking or ignoring the obvious fact that many other orbits of the same pair, widely differing from the one adopted in all material respects, will represent the observations just as well.

The Castor system has an annual movement in space of 0.″207 in the direction 248°.1, and this proper motion belongs to a star of 9.5 magnitude 73″ distant, thus probably forming one vast physical system.

MARKINGS IN THE SYRTIS MAJOR.

PERCIVAL LOWELL.

For Popular Astronomy.

Ever since Huygens discovered the rotation period of the planet by means of it, the Syrtis Major has been one of the best known markings upon Mars. Recognized by him as a permanent dark patch in 1659 it enabled him, and still more conclusively Cassini a little later, to time the planet's day. It was very early surmised to be an ocean and from its shape was called the Hour-glass Sea, a name of doubly happy significance since it had served as Martian hour-glass to observers on the Earth. A sea it continued to be considered by generations of astronomers. For over two hundred years its supposed aquatic character passed current

practically unquestioned. Its color seemed in fact conclusive of its constitution. Under the best observational conditions it showed of a deep blue-green; just the hue an ocean might be expected to exhibit. So firmly established indeed did its character appear to be that when W. H. Pickering conceived another explanation for the dark patches, deemed to be the Martian seas, his able iconoclastic theory forbore to include the Syrtis in the prescribed list and left it in continued enjoyment of its time-honored marine prerogative.

But tempora mutantur et nos mutamur in illis; even our conception of the character of the Syrtis Major. Unfortunately for the ocean-loving the character of the Syrtis Major must pass with other charming myths into the limbo of the past. For the great blue-green area is no ocean, no sea, no anything connected with water, but something very far removed from water: namely a vast track of vegetation.

The true character of the Syrtis Major first became apparent from the observations made here in the opposition of 1894. The argument I need but recapitulate as I have given it fully elsewhere. It is in brief: 1st that the polariscopic investigations of Professor W. H. Pickering showed no polarization from its surface while they did show polarization from the south polar sea which on other grounds we are convinced is water; 2d as the Martian season advanced light and dark markings appeared in in the Syrtis and continued after their appearance unchanged in position; 3d that still later the whole blue-green areas diminished in extent without producing any corresponding dark areas anywhere else on the planet. All three of which phenomena are incompatible with a water surface while being such as an area of vegetation should exhibit by its growth and subsequent decay as the Martian seasons advanced.

I propose in this paper to examine in detail the changes that occur in the Syrtis with the changes of the Martian year; for so peculiar are these changes that their examination while rendering it substantially certain that vegetation is their cause introduces some enigmas in our attempts at explanation of the special appearances that vegetation is constrained to adopt.

In the first place the appearance of markings is a Martian seasonal affair. As any intelligent reader demands to know in connection with any fact the more fundamental facts upon which it is based, it will be well to state the reasons upon which this statement rests. We will therefore take up, as typical, the phenomena first of 1894 and then of 1896. During the fore part, then, of the

last opposition, that is in June, 1894, when the observational conditions were in general similar to those of August of this year, the Syrtis was a dark marking of, roughly speaking, uniform hue throughout except for three things: the first was the deeper tint of its northern end; the second a dark strait-like band that joined it to the south polar sea, passing between Noachis and Hellas and then running parallel to, but somewhat off, the coast line of Aeria; and the third a similar strait joining it and the polar sea between Hellas and Ausonia. Now at this time it was May in the Martian southern hemisphere.

As the season advanced changes took place in the look of the Syrtis. No longer uniform throughout, the great dark area became gradually diversified with light bands and patches and dark lines. As time wore on the salience of these markings became more and more pronounced until by October and November—the August of its year—the Syrtis presented a very checkerboard-like effect. This was all a case of clarification, positive or negative. The color of the Syrtis, in places, faded out. Just such an effect would follow the change of vegetation from green to yellow and ochre, as spring passed toward autumn.

Now in August 1896, the planet was presented to the Earth under somewhat similiar observational condidions with what it had been in June 1894, save for one important difference: it was a month and two thirds later in the planet's year. And here it is worth noting parenthentically, because so easy of remembrance, that the regression in the date between opposition and opposition exactly marks the advance in the Martian seasons between those two epochs since at those times the two planets, being in the same longitude as seen from the Sun, are necessarily at the same correlative seasons of their years. The only correction to be introduced to this concordance is that which depends upon the eccentricities of their orbits which for general purposes may be neglected. In August, 1896, then, if seasonal changes were the cause of its surface features, these features should have looked as they did in October 1894 not as they did in June of that year, for the summer solstice of the planet's southern hemisphere took place in 1894 on August 31, in 1896 on July 13. This is precisely what occurred. The Syrtis in August 1896 looked as it had in October 1894; and this in spite of greater distance which would tend to hide such corroborating detail. Its appearance therefore confirmed what the previous observations had implied: that the change in look of the planet was not a question of distance, that is of differing ease of visibility, but a question

solely of the Martian time of year, that is a vegetational seasonal affair.

We will now go on to consider the markings in detail.

The markings that as the Martian season progresses make their appearance on the Syrtis are of two kinds: ones lighter than their surroundings, ones darker than the same. It will be seen in a moment that, as I have said, the sole discloser is a process of clarification, positive or negative. The lighter are the most easily recognizable; for which reason of them are those which have been suspected for the longest time and are most readily perceived.

Oenotria: The lighter markings are themselves of two kinds: rhomboidal areas and long causeway-like connections between the so-called continents, Aeria and Libya, and Hellas. Of the rhomboidal areas are Oenotria, nearest Aeria, and a second edition of it farther along toward Ausonia, in what properly speaking is not the Syrtis at all but the Mare Hadriaticum. These rhomboidal areas are made to appear such by bounding canals. They are in truth lighter patches whose limits depend upon something extrinsic to themselves.

Causeways. Much more interesting at first sight are the causeways. Of these there are four: Solis Pons, Lunae Pons, Pons Cometarum and Pons Stellarum. The drawings accompanying this paper show definitely but three: Solis Pons on the right, Lunae Pons on the left and Pons Stellarum between them. Pons Cometarum does not happen to be saliently shown. It lies in the very centre of the Syrtis, half-way from Pons Stellarum to Lunae Pons, alongside of the dark line running nearly due South in the Syrtis to Hellas.

Solis Pons. Solis Pons is a relatively long recognized marking. It was first seen at least 34 years ago; as it appears in drawings made in 1862 with Lord Rosse giant reflector. It appears again partially in Kaiser's drawings of 1864, and more or less *passim* since. It joins Hammonis Cornu to the northern end of Hellas slightly to the west of its extreme northern point. It is the most conspicuous of all the Pontes.

In 1894 it was first seen at this Observatory on about the 10th of the Martian August; this year as soon as observations began, on July 23, that is about July 1 Martian time.

Lunae Pons. Lunae Pons was first adumbrated in 1862 in the same drawings of Lord Rosse's that disclose the Solis Pons. It

* In my map in Mars I have called Solis Pons, Solis Promontorium; but Pons seems a better general name for all of these markings.

was not however, definitely seen till 1873 by Dr. Terby, in one of whose drawings of that year, that of the 24th of May, it appears unmistakably. It is next possible to identify a part of it in one of Trouvelot's drawings in 1884. It was not seen again apparently till it was detected at this Observatory about the 10th of the Martian August in 1894. This year it was first seen by Mr. Leo Brenner in Istria, not far from the time of the Martian summer solstice. It was evident here at the beginning of observations at the end of July, being much more conspicuous this year than in 1894.

Pons Cometarum. Pons Cometarum was first seen here, in 1894, at the same time as the other Pontes but was much less evident. It was again seen with them this year.

Pons Stellarum. Pons Stellarum was not seen till the date of the drawing accompanying this paper. It is the most difficult to see of all the Pontes so far detected.

Now what are these causeways? will be the question that at once suggests itself. It is not easy to give any rational answer; so utterly unlike are the phenomena from anything that happens on Earth. Certain helps, however, to an explanation we may note. It is practically assured that the lightening of the surface which renders them visible is due to a parching of that part of the country; what was green growth having passed into the sere and yellow leaf and giving to the land in consequence an ochre hue. The difficult matter is to explain why parching should occur in so definite a form. But here the canals come to our aid. For it would appear from the relative positions of the causeways and of the canals that the one lies alongside the other and that therefore it is not really the causeway that is responsible for its symmetric appearance but the straight canal by its side. In other words the parched area assumes its regular contour because the parching is not permitted to extend further. This brings us to a consideration of the next set of appearances in the Syrtis, the dark markings.

Dark Markings. These also are of two kinds, although the kinds are not the same as with the light markings: lines and spots. The lines are the "canals" in the dark regions first definitely detected as such by Mr. Douglass in 1894.

The Dosaron. Longest and most evident of these is the Dosaron. It is the long line that, starting from the bottom of the Syrtis runs straight up between Hellas and Noachis almost to the edge of the disc. Now the reader cannot fail to be struck instantly with its absolute straightness and its absolutely uniform

width or in other words with its appearance of artificiality. But the apparent artificiality is not all. On reflection he will remember that earlier in the Martian season there existed in this same place a swath of deeper tint than its surroundings joining the Syrtis to the south polar sea. This swath was not straight nor was it uniform in width. In short it bore no semblance of artificiality. It curved in a most fortuitous manner, was tolerably broad and generally uneven throughout. Later it faded in tint; so much so that in its southern portion after the vanishing of the polar sea it disappeared. When it had become faint enough there showed in its midst this long, narrow, even, straight line, the Dosaron, starting also from the bottom of the Syrtis and running through the center of the strip of country it had occupied but taking a direct course through the same. There could hardly be conceived a more patent proof of its artificiality.

For mark what was undoubtedly the state of things. Of natural causation was a belt of country lower than its surroundings which joined the polar regions to the Syrtis. This belt of country was by nature fertilized by water coming from the polar sea while adjacent land being higher escaped such quickening and remained perpetually barren, showing in consequence an ochre tint while this strip showed green. As soon as it became necessary to carry water artificially from the polar sea to the equatorial regions of the planet the most forthright expedient would be to run a canal through this already natural conduit.

The Orosines. The next line to be noted is one which starting from the same point in the Syrtis as the Dosaron runs almost due south to the middle of Hellas. It is the Orosines. Like the Dosaron it is perfectly straight and perfectly uniform in width. What is more it is of the same width as the latter. This width I make to be a little under one Martian degree or about 34 miles. It must not be supposed that this is all canal; it is probably the fertilized area, as I have said elsewhere, bordering the canal too narrow to be itself visible.

Now, definite as is the direction of the Orosines there is more in this apparent purpose than meets the eye in the drawings here shown. For although it does not appear in the drawings, there debauches at the point in Hellas where the Orosines reaches it, the most important canal in that region, the Alpheus, and, what is yet more significant, it runs directly south toward the south circumpolar regions. The Orosines, then, like the Dosaron, is part of a chain of connections between the Syrtis and the south polar sea.

Of lateral canals we may take first a new one, seen that is for the first time in the first of the above drawings, and not yet named. It runs athwart the Syrtis about midway between Lybia and Hellas but as will be seen it does so with a purpose for it joins the embouchure of the Typhon to the embouchure of the Achates which comes down from the south through the middle of Ausonia where Lemuria meets the latter.

From the same embouchure of the Typhon another canal leaves for the Sesamus at the western end of Ausonia. This is in general parallel to the Solis Pons, and to the Aeolus bordering its southern edge. In fact the canals in the dark regions show a propensity to parallelism.

Erymanthus. This is shown again by the next canal the Erymathus which starts from the junction of the Dosaron and Orosines and runs to the middle of Lemuria.

The Galaesus. The Galaesus leaves the Syrtis Minor (on the left-hand side of drawings 4 and 5 near the terminator) and runs to the midddle of the north end of Ausonia where it meets the Orosines. This plays in the economy of the Syrtis Minor the same part that the Dosaron does in that of the Syrtis Major.

The Oceanus. The Oceanus is shown coming down to a junction with the Erymanthus at a point farther than was seen at the last opposition and represented in the map.

The Hylias and Carpis. The Hylias and Carpis make another pair of parallels, the one leaving the Hammonis Cornu for the centre of Lemuria, the other from the mouth of the Typhon to the western end of Libya.

The Aeolus. Finally the Aeolus runs from the Hammonis Cornu to Hellas, on the southern edge of the Solis Pons, exemplifying what I have said of the connection between the causeways and the canals.

So much for the canals in the Syrtis Major and the adjoining Hadriaticum Mare. We are now to consider another no less interesting feature of the region. In drawings 4 and 5, by Mr. Douglass, will be seen four dark spots situated in various parts of it.

One stands in its very heart, at the junction of the Dosaron and Orosines. Another is seen at the junction of the Erymanthus and Oceanus. A third appears further upon the Erymanthus at its meeting point with the Galaesus. While a fourth lies on the Dosaron where it is crossed by the Oceanus.

These spots are quite similar to the oases in the light regions. They are found just as the latter are at the junctions of canals

and never anywhere else. That they are also oases, like their desert fellows, is more than probable; places where for some reason the canals meet, which thus become specially fertile spots. The water they receive enables them to keep green after the regions about them have become dried, or partially dried, and through this continuance of verdure are they rendered visible to us.

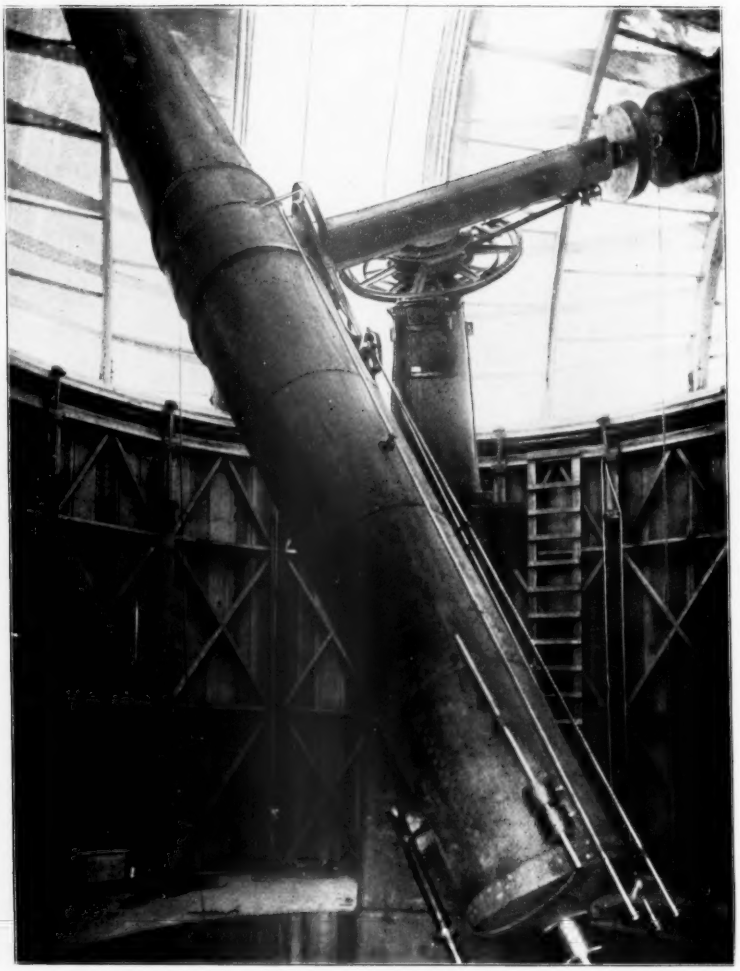
Although the changes we note are seasonal changes, nevertheless the seasons do not play the same part in Martian floral economy that they do with us. The meteorlogical conditions on the two planets differ markedly. On Mars there is a great scarcity of water and water when procurable has a much greater effectiveness owing to the general climatic conditions of the planet than would be possible on Earth. For some reason which we do not yet fully comprehend the mean temperature on Mars is much higher than the mean temperature of the Earth. Although we know not the cause, the effect is patent. Whenever therefore water is present it acts to much greater effect. We may liken Mars to a vast equatorial desert which needs but one thing, water, to blossom as the rose.

As a last item of the Martian canal economy may be mentioned spots which are neither in the light regions nor yet in the dark ones but as it were in both. These spots, which unlike the others, do not appear to be round but angular, are found at the points where the canals in the light regions debouch into the dark. Two of them will be seen in Mr. Douglass' two drawings, one at the mouth of the Typhon, one at that of the Phison in the Mare Icarium. They too are doubtless oasis-like, but as I have said elsewhere, they also may with propriety be looked on as a sort of relay stations for the water in the course of its long journeyings from one part of the planet to another.

Of the light regions proper I do not here propose to speak, as my subject in this paper is simply the Syrtis Major teaching by example. For those who are interested, however, I may say that the canals in the light regions shown in the drawings are, beginning on the left; the Cambyses; the Nymphaeus possibly or possibly a new canal; the Amenthes; the Triton; the Astapus; the Nepenthes; a new one; the Boreosyrtis; the Nilosyrtis; the Astusapis; another new one; the Astaboras; the Typhon; the Phison; the Protonilus; the Euphrates and Orontes. The oases are two new ones at the junctions of the Astapus, the Amenthes and the Boresyrtis and of the Nilosyrtis and Phison respectively.

LOWELL OBSERVATORY, November, Flagstaff, A. T.

PLATE XXX.



THE NEW 24-INCH REFRACTOR OF THE LOWELL OBSERVATORY.

A SKETCH OF THE NEW 24-INCH REFRACTOR OF THE LOWELL OBSERVATORY.

T. J. J. SEE.

FOR POPULAR ASTRONOMY.

In May, 1895 Alvan Clark & Sons, of Cambridgeport, Mass., received an order from Percival Lowell, Esq., for a 24-inch refracting telescope of the finest quality and most approved design. Within less than one year from the receipt of the order the lenses were finished and tested, and the instrument practically ready for use in the Observatory. Such energetic work was never before attempted in the construction of any large telescope, and the accomplishment of so great a task is equally a matter of wonder and of admiration to American astronomers. It may well be entered upon the annals of American Science as a significant achievement in the art of telescope making, which this justly celebrated firm has developed and perfected. The accompanying illustration represents the new 24-inch Clark refractor as it now stands in the Observatory at Flagstaff. The temporary dome is the same as was used two years ago for the 18-inch, when so many important observations were made on the planet Mars.

Carefully packed against damage in the transit, the new glass was brought to Flagstaff, July 22; next day it was mounted in the great tube which had already been placed in position by Mr. Douglass, who preceded Mr. Lowell and Mr. Clark.

The tube of the great telescope was specially designed by the Clarks to give stiffness and rigidity and to ensure the firmness so desirable in the finest planetary observations. Mr. Lowell's desire to secure great stability has been fully met in the construction of the 24-inch, which has by far the heaviest and strongest mounting of any telescope of this size in the world. The following details of the new instrument may be of interest to the readers of POPULAR ASTRONOMY:

(1). The object-glass has a clear aperture of 24-inches and a focal length of 31 feet; the glass disks from which the lenses were made were cast in Paris by the celebrated firm of Mantois. Perfectly pure and absolutely without a flaw, they weighed in the rough approximately 200 pounds; when finished the weight was found to be reduced to about 150 pounds. The figuring accords with the usual plan adopted by Alvan Clark & Sons; the crown glass is of equal curves and placed in front. The glasses

are separated by about 4-inches and set neatly in a cast iron cell secured to the great tube by strong screws. The cell is provided with six elliptical holes large enough to allow the insertion of the hand between the glasses for the purpose of cleaning the inside surfaces and to permit an ample circulation of air. By turning a ring on the outside of the cell all the holes are closed against dust and foreign matter, so that the glasses are carefully shut in on all sides except that exposed to the heavenly bodies. There is also a hole in the tube just behind the lenses which allows the back surface to be cleaned without interfering with the adjustment.

(2). The illustration shows that the tube is symetrical, and beautifully designed—swelling gently in the middle to a diameter of 33 inches, and tapering toward either end; it is of sheet steel and weighs about two tons; the central section which supports the whole is of cast iron and very strong.

(3). The steel axes rest in cylindrical bearings, and are enclosed in cases which exclude dust; pips are provided for oiling the machinery.

The polar axis has a diameter of $8\frac{1}{3}$-inches at the upper, $6\frac{2}{3}$-inches at the lower end; the declination axis varies in diameter from 8 to $5\frac{3}{8}$ inches. The whole movable part of the telescope including counterpoise weighs approximately six tons; the pressure is taken from the upper bearing of the polar axis by a single large friction roller 20 inches in diameter.

(4). The polar axis is adjustable to any latitude within 45° of the equator, so that the telescope can be used in any part of the Earth where good seeing is available.

(5). The right ascension and declination circles are respectively $34\frac{1}{2}$ and 30 inches in diameter, and carefully graduated; a finder is provided for expediting the work of setting and keeping the object in the field of view.

(6). The pier is of cast iron, made in sections and bolted together so as to be very firm and yet of such weight that the pieces are easily moved.

(7). The driving clock is placed outside the pier so that all the machinery is easily accessible; it is wound from the floor, and regulated by an electric control; the train is operated by an independent clock and controlled by a Bond spring governor. A bell notifies the observer when the clock needs winding.

(8). The micrometer is constructed on the Burnham model, in the form adopted by Alvan Clark & Sons, and is provided with all the necessary adjustments and with apparatus for illuminat-

ing the wires. The field of view is perfectly dark, so that the faintest objects can be seen in the immediate neighborhood of the threads.

(9). Clamping and slow motion in right ascension and declination are effected by the observer at the eye end, without arising from the observing chair.

From the above statement it will be seen that the Lowell Observatory now possesses one of the most powerful telescopes in the world. It is a matter of great congratulation that it is expressly designed to be located, not, as so many great instruments are, in the fog of low altitudes or in the dense air of smoky cities, but in elevated tropical or sub-tropical regions where the best seeing is afforded. When located in a dry region such as Arizona or the Mexican plateau, at an elevation which leaves the worst part of the atmosphere behind, it is reasonable to suppose that this instrument will show anything which can be seen with any existing telescope.

It is recognized by astronomers that for most kinds of work the mere size of a telescope, after a certain aperture has been reached, is of small importance compared to the atmosphere through which the observer must look. Thus the telescopes on our eastern coast suffer from the winds and vapors of the Atlantic ocean, and, as a result, extremely good seeing is comparatively rare. The mere density of pure air is not so great an obstruction to vision; the principal obstacle arises from impurities such as smoke and the haze incident to water vapor, and above all conflicting currents of warm and cold air when laden with vapor. These obstacles exist at nearly all low altitudes and render the images of a star either blurred and unsteady, or hazy and nebulous. The seeing is thus injured in the most conspicuous manner, and the best results are well-nigh unattainable.

All delicate work on planetary detail or on close and difficult double stars, depends on good seeing. So fully were Mr. Lowell and Mr. Douglass impressed with this view, from their work at Flagstaff two years ago, that along with the order for the 24-inch came the decision to seek the best air to be found on the face of the Earth.

Hence the plan to take the Observatory nearer the equator, and if practicable to even a higher elevation than Flagstaff (7,250 feet). On the Mexican plateau it is believed the seeing will be as nearly ideal as can be had in North America. The seeing at Flagstaff during the spring, summer and autumn is practically all that can be desired, but during the snowy winter it is less favorable.

Some of the results already obtained with the new 24-inch may serve as a test both of the seeing here, and of the quality of the telescope. Besides the extremely delicate phenomena on the planets Mars, Venus and Mercury, of which the writer has seen a considerable part, the new telescope has revealed many close and difficult double stars. The net work of canals on Mars, and the faint but yet indisputable markings on Venus and Mercury may be regarded as test objects par excellence both of telescope and of atmosphere; these have been seen and drawn by every member of the Observatory and are yielding results of the highest interest.

The writer's rediscovery of the companion of Sirius and his discovery of faint companions of θ Scorpii, α Piscis Australis, ϵ Sagittarii, β Delphini and of smaller close doubles at altitudes not surpassing 15° may be regarded as testimony for the excellence of Clark's latest great telescope. On the whole every lover of astronomy has cause to congratulate Mr. Lowell on the performance of his splendid glass and on his wise decision to seek a region of the Earth for its location where the seeing is equally good.

LOWELL OBSERVATORY,
Flagstaff, Arizona, 1896.

THE SEAS OF MARS, INUNDATIONS, MELTING OF THE POLAR SNOWS, ETC.*

BY J. R. H.

Professor Pickering (*Astronomy and Astro-Physics*, Vol. XI, p. 849) sums up his observations, made during the opposition of Mars, in 1892. The paragraphs referring to the seas are:

(3). "There are two permanently dark regions upon the planet, which under favorable circumstances appear blue, and are presumably water."

(5). "Except the two very dark regions referred to above all of the shaded regions upon the planet have at times a greenish tint. At other times they appear perfectly colorless. Clearly marked green regions are sometimes seen near the poles."

(7). "Through the shaded portions run certain curved branching dark lines. They are too wide for rivers, but may indicate their courses."

* This article has been held some time. Though late it should have place in current thought pertaining to Mars.

Professor Pickering also mentions (p. 669) that several of the more strongly marked canals cross the oceans, and remarks that if both are water, there is some anomaly here.

Professor Pickering evidently inclines to the view that these so-called oceans are land. But the lines separating the shaded from the bright areas bear a strong resemblance to coast-lines. On this account it seems to me probable that these shaded areas represent beds of oceans, although now possibly dry. And the observations seem more consonant with the supposition that they are not entirely dried up; viz., with the following hypothesis.

The oceans of Mars are mere remnants of former oceans, and are in general very shallow. In two places, however, they are still deep. Now shallow water varies in color with the angle of the incident light, while deep water does not change nearly so much. In our deep seas ocean currents have no effect on the bottoms; in the shallow Martian seas, however, it would be different; there they would scour out beds for themselves like rivers, only wider. I think this the most natural explanation of the dark curved lines. The canals, also, which I take to be cracks in the crust, not necessarily full of water, but generally depending on the presence of water for their visibility, would be visible under very favorable circumstances, through the shallow water, when running across the bottoms. Possibly in some cases the canals may have determined the course of ocean currents, as they probably have the course of rivers upon land, and in these cases they are scoured out and kept from silting up by these currents.

Besides these shaded areas, generally regarded as sea, there are the doubtful regions proper, as Ogygis Regio, Noachis Regio, etc. These are not all alike; some, as Deucalionis Regio, partake more of a continental character; others, as Ogygis Regio, of a maritime. Besides this diversity of aspect, they are essentially variable; the same region sometimes appearing as land, sometimes as sea. It may be remarked that they show a marked tendency to assume a whitish coloration, generally a dirty white tinge, sometimes so brilliant as to be comparable with the polar snows. This has been ascribed to clouds overhanging sandbanks, and in some cases even to snow on the summit of lofty mountains. Their apparent disappearance has been ascribed to submergence. This is obviously inconsistent with the hypothesis of mountains, and in itself it is hardly satisfactory, from the difficulty of suggesting an adequate cause for these inundations. I do not deny that there are such; I only say that as they are hard to account for, it may be well to have an alternative hypothesis.

The one I am about to bring forward may seem fanciful, but at least it is not impossible, it is free from inconsistencies, and it explains the observed facts fairly well.

I have said that the Martian seas are mere remnants of seas formerly more extensive and deeper. Now it seems very probable that these were salt like our own sea. By "salt" I do not mean that the principal dissolved ingredient was sodium chloride, though I think it not unlikely that it was; I only mean that the water contained *some* salt or salts in solution, and that it is not unlikely that the strength was comparable with that of our own sea. Now as the quantity of water diminished, the strength must have increased, so that the point of saturation may long ago have been reached, and the excess of salt thrown down in crystals on the ocean floor. (If this is so, the bed being brilliantly white, it would have more effect in modifying the color of shallow water than a dark-colored bed would have). Now to fix our ideas, take Noachis Regio for example. I suggest that instead of being a sand-bank, it is a kind of shoal composed of numerous rocks and very small islands, rising but little above sea-level. When these rocks were wetted, as by waves during the prevalence of a high wind, they would appear darkish like the sea, and the region could hardly be distinguished therefrom. As soon as the waves subsided, and the rocks dried, the salt in the brine would be left behind as a whitish efflorescence, giving the region a more continental aspect than it otherwise would have. It is possible that this may help to give the dirty-white tint; I am inclined to think, however, that this is in general due to clouds, as it has been observed to become more decided near the margins of the disc, *i. e.* at morning and evening, when we might expect condensation to occur.

The above explanation may also be true for Deucalionis Regio, Pyrrhæ Regio, Ogygis Regio, Protei Regio, Yaonis Regio, Xisuthri Regio, and the islands Japygia, Japeti, Œnotria, Cimmeria and Scheria.

In some of these the extent of land predominates over that of sea, in others it is *vice versa*. In normal circumstances the former will have more of a continental aspect, the latter of a maritime.

The principal of these shoals may be called the Great Shoal, and lies south of the Hourglass Sea. It stretches from the north of Cassini land to Mädler Continent. Near Cassini L. land predominates, and it is here called Dreyer Island. To the west of Dreyer Island sea predominates, except in the middle, in about longitude 300°, where there is a patch of rocks called Hirst Islands. After

this, sea again predominates to about longitude 345°, when land again begins to get the upper hand, and does so more and more till Mädler Continent is reached. This latter part is called Phillip's Island. A branch of the main shoal forms M. Schiaparelli's Œnotria. Another smaller and less marked branch runs from the northeast corner of Dreyer Island across Flammarion Sea. When the Great Shoal appears as land, Herschel II Strait assumes the appearance it has on the old drawings of a ball suspended by a ribbon. I made a copy of M. Flammarion's map, (*La Planète Mars* p. 69) and marked the shoals on it in yellow and the deep sea in blue; the resulting chart was curiously like the old drawings, and Herschel II Strait had exactly the same appearance as on Beer and Mädler's sketches (*La Planète Mars* p. 105).

I remarked that these seas appear to be only remnants of former more extensive seas. Is it possible to determine any of the former coasts? I believe it is, with reasonable probability.

The old coast must have been indented with bays like the present, and these bays have probably left traces. The nature of these can be inferred from Schiaparelli's sketch of his observation of 20 June, 1890, (*La Planète Mars*, p. 476). At the time of observation, obviously, from some reason, there was but little water in the sea to the S. of Beer Continent, and in consequence Phillip's Island appears enlarged and attached to the continent, being only separated by a canal, which occupies the place of Herschel's II Strait. First Meridian Bay and Schmidt's Bay are transformed into inland lakes. The observation may be regarded as in a sense prefiguring the future aspect of the region, and these lakes as representing what these bays will become.

The inference is that the old bays are represented by inland or semi-inland lakes, and it is generally not very difficult to determine which was the land and which the sea side. A consideration which frequently helps us may be seen by examining the lake corresponding to First Meridian Bay. On the side of Phillip's Island, that is, the sea-side, the land is deeply eaten into, suggesting that it has been eroded by a current from the mouth of the bay, but the contour is fairly regular; while the landward side presents two long processes. These represent estuaries, and are never found on the seaward side of a bay, which is always approximately regular. This also gives a criterion distinguishing lakes which may have been ancient bays from lakes which cannot possibly have been, viz. that lakes which are very irregular in form all around cannot have been bays, and lakes which are regular all round probably have not.

The determination of the coasts between the bays is more difficult, and frequently cannot be accomplished. The following considerations help in it. (1) In many cases the old coasts persist as edges of narrow straits, (as the Nasmyth Inlet). (2) Coasts which appear to be mountainous, as evinced by clouds fringing the seas, are presumably ancient.

I will give some of the results without going into the grounds whence they are deduced.

The coast of Beer Continent bordering on the Hourglass Sea, and its south coast are ancient. I am unable to give a definite opinion as to the south coast of Mädler Continent. Thaumasia is new. So are Icaris, Aurea Cherso, Tempe, Laplace Land, Leverrier Land. Webb Land and Cassini Land were formerly islands unattached to the continent. The peninsulas of Atlantis and Hesperia are new. The north coasts of Schiaparelli and Maraldi Seas are ancient. From the mouth of the Lethes to the Hourglass Sea, the present coast is new. If Schiaparelli's drawing (*La Planète Mars* p. 439) of changes in the appearance of Libya be referred to, it will be seen that the dotted line 1884-1888 terminates on the coast of the Hourglass Sea at a point in Isidis Regio. From this point a chain of mountains or lofty hills runs obliquely across Land Moeris to near the mouth of the Syrtis Parva. This line of mountains marks the old coast. Land Moeris is the old mouth of the Nepenthes. The new land (part of Libya, and of Isidis Regio) is low, and liable to inundations. Land Ismenius is the old mouth of the Euphrates and Astaboras, Land Niliacus of a number of rivers all flowing northerly, Land Tithonius of the Chrysorrhoas and Fortunæ, and Land Phoenicis of the Iris, etc. I am in doubt whether Trivium Charontis, Propontis, and Nodus Gordii, are to be regarded as ancient bays or not.

Mr. Proctor gave a discussion quoted at p. 398 of *La Planète Mars*. In it he remarks that if we take the masses of the seas as proportional to the masses of the planets, the total quantity of water on each acre of Mars is less than the total quantity on each acre of the Earth in the ratio of 7 to 18. But this alone will not account for the lessened water area. If we take the total *volume* as given in this way, we find that the seas must have an average depth of over half that of ours. This seems very unlikely. All the evidence we have points to the conclusion that the seas are very shallow. But in any case it seems to me far from probable that the planets contained originally the same elements *in the same proportions*, or even granting that they did origin-

ally, that the same proportions persisted at the time of the formation of the seas, or finally that they persist *now*.

(I have added some reasoning on this point to the end of this article as a note; I do not insert it here, in order not to break continuity).

Inundations.—Besides the changes in appearance of the doubtful regions, somewhat similar changes have at times been noticed in other places, notably Libya and Hellas. I said I did not believe that in the case of the doubtful areas, we had to deal with real inundations and I suggested a hypothesis to explain such cases.

The instances to which I am now referring are different; Libya can hardly be termed doubtful; its general appearance is decidedly continental; and Hellas, although marked as doubtful on M. Flammarion's map, seems to differ in many respects from the other areas so marked. In particular it may be remarked that the aspects of the doubtful areas vary rapidly and irregularly, while Libya and Hellas remain nearly the same throughout one opposition.

These changes may be due to real submergencies, or they may be only apparent; if Professor Pickering is right in his view as to the limited extent of water area, they *must* be only apparent, and the only suggestion I can make is that they are caused by variations of vegetation; but even for the really doubtful areas, as Deucalionis Regio, this hypothesis is far from satisfactory, and in my opinion, totally inapplicable to Libya, as there the water (or vegetation) while covering part of the land receded from the regions to the south. (*La Planète Mars*, p. 403).

This certainly looks like a real inundation, and the resemblance is increased by the fact that, just before, Libya assumed the dirty-white tint at the edge of the disc, as though it had already been flooded to a certain extent, and transformed into a doubtful region.

But an inundation cannot occur without *some* cause; and the two most obvious causes here, the tides, and depression of the land, seem unlikely in Mars; the first, because its tides are probably of only infinitesimal magnitude, and in any case these apparent floodings persist too long to be due to this cause; and the second, because such rapid depressions do not occur on the Earth, and it is hardly likely that the volcanic energies of Mars are active still to such an extent. Accordingly, it seems to me that we should look on the reality of the appearance with extreme suspicion, and try to find an explanation on the hypothesis

that it is only apparent, and only when unable to do this, should we admit the supposition that it is real.

In the cases I have cited, Libya and Hellas, it seems to me that we are forced to the supposition that the inundations were real.

And since the tides and depressions of the land are excluded we must find some other explanation. The most obvious, and that usually given, is the melting of the polar snows.

RELATIVE MOTION OF THE STARS IN THE LINE OF SIGHT.

EDWARD C. PICKERING.

The determination of the motion of the stars in the line of sight by means of the spectroscope is one of the most important problems in astronomy. The greatest, and almost the only, objection to the objective prism is that it has thus far failed to determine this quantity. Placing the prism in front of the objective has many advantages over the use of a slit spectroscope. Instead of photographing one star at a time, more than a thousand have, in many instances, been photographed upon a single plate. In fact, our only knowledge of the photographic spectra of the fainter stars is derived from plates obtained with an objective prism. The wave lengths of the lines can also generally be determined equally well by either method, since in the spectrum of almost every star numerous lines are present whose wave lengths have already been accurately determined in the solar spectrum. The wave lengths of other lines can be better determined differentially from these than directly by a comparison spectrum. Nearly all of the Draper Memorial spectra have been photographed by means of objective prisms. Numerous unsuccessful attempts have been made here, ever since this work was undertaken, to determine with an objective prism the approach and recession of the stars (Annals XXVI, p. xx). Among other methods which have been tried may be mentioned the use of an absorbing medium like didymium, the variation in length of the spectra, and the use of a point of reference formed by throwing an auxiliary image of the star into the field by means of a small achromatic prism, or by reflecting prisms. Recently experiments have been made by comparing the corresponding lines in the spectra of different stars with their images taken on another plate without the prism and with the film reversed. A discussion of this method by the writer with Mr. Edward S. King has led to

the method described below, which promises to determine accurately the relative motion of two or more stars in the line of sight if they are near enough together to be photographed upon the same plate. Let A and B be two such stars, A being at rest and B approaching with such a velocity that a given line in its spectrum is deviated by the amount d, and let a photograph be taken in such a position that the end of shorter wave length of the spectrum of B is turned towards that of A. Then the distance between the images of the given line in the two spectra will be less by the amount d. than it would be if both stars were at rest. Now let another photograph be taken in which, by turning the prism 180°, the spectra are turned by the same amount, so that the end of greater wave length of the spectrum of B is turned towards that of A. The distance between the two lines will then be increased by an equal amount. If two such photographs are superposed and the images of the reference line in the spectra of A are made to coincide, its images in the spectra of B will deviate by $2d$. To apply this method, a photograph of a region a little east of the meridian is taken in the usual way. Then the telescope is reversed and a second photograph of the same region is taken on a plate with the film side away from the star, so that the photograph is taken through the glass. As both photographs are taken near the meridian the lines will be nearly perpendicular to the length of the spectrum, while, at a large hour angle, if the exposure is long, and the spectra narrow, the lines will cross them obliquely, owing to the differential refraction. Reversing the telescope turns the prisms, and with them the spectra exactly 180°. In making the examination the plates are placed film to film so that the spectra are side by side, and one is moved over the other by means of a micrometer screw. The corresponding lines in the two images of each star in turn are made to coincide, and the difference in the readings gives double the displacement of the line. An error in orienting the plates would affect the results when the stars compared are not in the same right ascension. This source of error may probably be made insensible in several ways, such as by marking a reference line on each plate, or by turning the prisms so that their edges are perpendicular to the line connecting the stars and moving the plate slowly by clock-work. Since the ends only of the lines are compared, narrow spectra may be used, and faint stars may therefore be measured. Experiments are now in progress with a cylindrical lens, by which it is expected that the accuracy of setting on lines in very narrow spectra can be still further increased.

Only preliminary tests of this method can be made at Cambridge at present, as our three best prisms are now in Peru. Two photographs of 101 and 102 Herculis were, however, taken on October 9, 1896, with a single prism, giving poor definition, but showed by inspection that the first of these stars was approaching more rapidly than the second. Measures by Mr. King of the lines $H\varepsilon$ and $H\zeta$ indicated the relative velocities 87 and 94 kilometres a second respectively. These results are not corrected for the position of the prism and other sources of instrumental error. The probable error as indicated by the accordance of the individual settings is 5 kilometres in each case. An inspection of two photographs of the Pleiades shows that the relative motions of the seven brightest stars in the group, although perhaps measureable, is not appreciable to the eye, and probably does not exceed 30 kilometres a second.

The advantages of the above method are, first, the directness of the determination of the motion; second, that double the deviation is measured; and third, that as the ends of two similar lines are made to coincide, the accidental errors of measurement are much less than when each in turn is bisected by a spider line. Since each line in the spectrum may be used a large number of independent determinations may be obtained from one pair of plates. On the other hand, as it is only necessary that one line should be in focus, a visual telescope may be employed; that is, one uncorrected for the photographic rays. No corrections need be applied for the motion of the Sun in space or of the Earth in its orbit, since they will affect both stars equally.

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PRACTICAL SUGGESTIONS.

ECLIPSES.

J. MORRISON, M. A., M. D., PH. D.

FOR POPULAR ASTRONOMY.

From time immemorial eclipses, and especially those of the Sun, have been universally regarded as the most interesting and striking astronomical phenomena. Solar eclipses furnish astronomers with the best opportunity of testing the accuracy of the Solar and Lunar Tables and also for studying the physical

constitution of the Sun. The calculation of all the circumstances connected with eclipses, involves considerable labor and is performed by several methods according to the accuracy which is desired.

In ancient times it was discovered that eclipses both of the Sun and Moon repeat themselves after an interval or cycle of 18 years and 11 or 12 days, known by the name of the Chaldean period or the Saros. This remarkable cycle is due to the fact that 242 *nodal* revolutions of the Moon are performed *in nearly* the same period as 19 *nodal* revolutions of the Sun or in other terms, 223 lunations or synodical revolutions of the Moon require for their completion 6585.321222 days or 18.029627 Julian years or 18.03001 + tropical years, that is, 18 common years and 11 or 12 days according to the number of leap years contained in the period.

Another remarkable relation in connection with this cycle is that 239 anomalistic revolutions of the Moon are performed in 6585.549 days which differs from the above by less than one-fourth of a day. Hence it follows that at the end of a Saros, the Sun, Moon and the Moon's node are found almost in their original relation, nor is this all, the Moon's mean anomaly has the same value to within $\pm 3^\circ$ and the Sun's mean anomaly to within 12°. These circumstances are due to the fact that the times of revolution of Sun, Moon and the Moon's node and perigee are all close multiples of 18 years. The exact changes in the elements during a Saros or 223 lunations are as follows:

In the argument of latitude	$-28'.5$
In the Moon's mean anomaly	$-\ 2^\circ.8$
In the Sun's mean anomaly	$+10^\circ.5$
In the distance of the Moon's perigee from node	$+\ 2^\circ.4$
In the distance of the Sun's perigee from node	$-11^\circ.0$

It is quite evident then that owing to these slight changes, the mean place of the Moon and all its larger inequalities will attain the same or very nearly the same values at the end of the period that they had at the beginning, and not only these, but the parallax and semidiameter of the Moon also return to their former values.

In consequence of the retrograde motion of $28'.5$ from the node during each Saros the corresponding eclipses in succeeding cycles will be subject to slow progressive changes in their magnitude and duration. A series of such eclipses will begin with a very small partial eclipse near one pole of the Earth and gradually in-

crease for about eleven or twelve recurrences after which it will become annular or total near the same pole. Some forty or forty-five such eclipses will then follow, the line of annular or total eclipse moving slowly toward the other pole, it will then again become partial and finally cease altogether. The series will contain about 70 eclipses of the Sun, embracing a period of about 1260 years, after which a new series will begin and pass through the same changes.

As already stated, there are several methods of computing eclipses.

1st. There is the graphical method described in Loomis's Practical Astronomy and other similar works. This method does not of course aim at anything like accuracy: it is in fact only a rough approximation at best, and is not to be recommended.

2d. The parallactic method which consists in assuming one or more times for the beginning and end of the eclipse and then computing for the given place, the parallax in R. A. and Decl. which when applied to the true R. A. and Decl. of the Sun and Moon will give their apparent places. The beginning or end of the eclipse will of course take place when the apparent distance between the centres of the Sun and Moon, is equal to the sum of their augmented semi-diameters. This method is fully explained in the work already alluded to and is capable of a high degree of accuracy but it involves considerable labor and lacks the generality of other methods.

3rd. Woolhouse's method which may be regarded to some extent as an extension of the preceding. It is employed in the English Nautical Almanac and gives all the circumstances of an eclipse with all the accuracy desired. The student who wishes to become acquainted with this method will find it fully explained in the appendix of the English Nautical Almanac for the year 1836.

4th. Bessel's method employed in the American Ephemeris and Nautical Almanac, is the one which we propose to explain in the following papers. It furnishes all the circumstances of an eclipse with a degree of accuracy which leaves little or nothing further to be desired.

Whatever method is employed, the first thing to be done is to determine the elements of the eclipse which are as follows:

Greenwich Mean Time of ☌ of Sun and Moon in R. A.

R. A. of the Sun and Moon (at this date).

Decl. of the Sun and Moon.

Sun and Moon's hourly motions in R. A. and Decl.

Sun and Moon's equatorial horizontal parallaxes.

Sun and Moon's semi diameters.

To compute the first, find from the ephemeris, the R. A. of the Sun and Moon for several hours preceding and following conjunction. These quantities are already given for the Moon, but will have to be carefully interpolated for the Sun. Subtract the Moon's R. A. from that of the Sun and let these differences be denoted by α_2, α_1, α_0, α_{-1}, α_{-2}, α_{-3}, etc., we are now to find the date at which this difference becomes zero. A simple inspection will show the dates between which conjunction will take place. Form the first, second and third differences in the usual way and put b = 1st diff., $c = \frac{1}{2}(c_0 + c_1)$, *i. e.*, half the sum of the second difference which precede and follow b, and d = 3d diff. Then we shall have for any term of the series

$$a^{(t)} = a_0 + tb + \frac{t(t-1)}{1,2} \cdot c + \frac{t(t-1)(t-\frac{1}{2})}{1,2,3} \cdot d + \text{etc.}$$

At the time of conjunction $a^{(t)} = 0$, putting then the second member equal to zero and solving for t we have, omitting the square and higher powers

$$t = \frac{a_0}{-b + \frac{1}{2}c - \frac{1}{12}d} \quad \text{or} = \frac{a_0}{\frac{1}{2}c - b} \qquad (45)$$

when the 3d diff. is neglected.

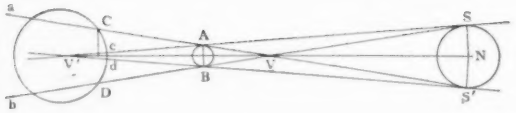
A check on the accuracy of this date will be found by computing the R. A. of the Sun and Moon which must be equal, and if not, the time must be corrected by a simple interpolation until the computed R. A's are exactly equal. The other elements are now interpolated for this date from the data in the ephemeris.

When an eclipse begins or ends at a place, the limbs of the Sun and Moon are in apparent contact and the observer is situated on the surface of the cone which envelopes the two bodies. An inspection of the diagrams shows that there are two such enveloping cones.

First. The cone aVb whose vertex V lies *between* the Sun and Moon, is called the penumbral cone and

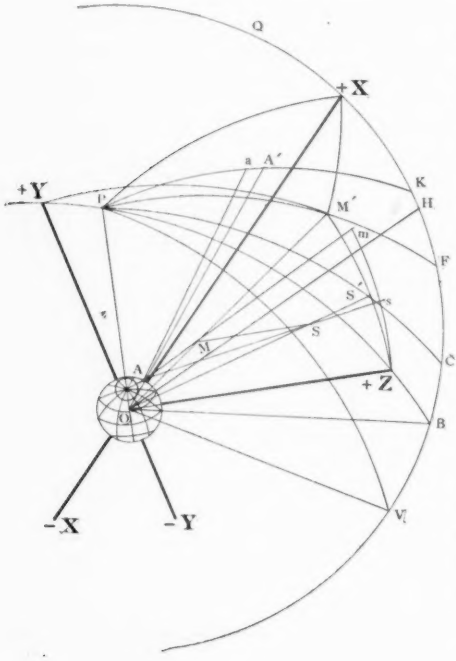
Second, the cone $SV'S'$ whose vertex V' falls beyond the Moon towards the Earth, is called the umbral cone or cone of total shadow.

An observer at C or D sees the limbs, AS' or BS in apparent *ex-*



terior contact which are the beginning and ending of the entire eclipse, but if the observer be at *c* or *d* he sees the limbs *AS* or *BS'* in apparent *interior contact* which are the beginning and ending of the total or annular eclipse according as the observer is nearer to or farther from the Moon than the vertex *V'* of the umbral cone. The eclipse is partial at points between *Cc* and *Dd*, and total between *c* and *d*. *V'VN* is the axis of the shadow and the condition that an eclipse may occur at any given place, *C*, for instance, is that its distance from the axis must be equal to the radius of the shadow for that point and the analytical expression which fulfills this condition, is the fundamental equation in the theory of eclipses.

Position of the Axis of the Shadow.



Let *O* be the centre of the Earth, *A* a place on its surface, *S* the Sun's centre and *M* the Moon's and *S'*, *M'*, *A'*, *s* and *m* the points in which *OS*, *OM*, *OA*, *AS* and *AM* produced, meet the celestial sphere, hence *S'* and *M'* are the *true* places of the Sun and Moon and *s* and *m* their apparent places, and *A'* is the *geocentric* zenith of the place *A*.

Again, let *a* be the *geographical* zenith of the place *A*, *OZ* a straight line *parallel* to *MS* and meeting the celestial sphere in *Z*, *VQ* the equator, *V* the vernal equinox, *P* the

north pole of the equator, and PB, PC, PF and PK declination circles through Z, S', M' and A' and a. The line MS joining the centres of Sun and Moon meets the celestial sphere in the common vanishing point of all lines parallel to it, that is, in the point Z, and therefore the position of the axis of the cone will be determined by the R. A. and Decl. of this point.

Let $r = OM$ the Moon's distance.
$r' = OS$ the Sun's distance.
$G = MS$ the distance between the centres of Sun and Moon.
$\alpha = VF$ the Moon's R. A.
$\delta = FM$ " " Decl.
$\alpha' = VC$, the Sun's R. A.
$\delta' = CS$, " " Decl.
$a = VB$, the R. A. of the point Z.
$d = BZ$, the Decl. " " "

Make VH a quadrant, then OV, OH and OP will be a system of rectangular axes having the centre of the Earth as origin and the axis of X or OV the line through the equinoctial points, the axis of Y or OH the intersection of the planes of the equator and solstitial colure and the axis of Z or OP the axis of the equator. Also let x be positive towards the vernal equinox V; y positive towards that point of the equator whose R. A. is 90° and z positive towards the north, then the coördinates will be

of the Sun	and	of the Moon
$x_0' = r' \cos \delta' \cos \alpha'$		$x_0 = r \cos \delta \cos \alpha$
$y_0' = r' \cos \delta' \sin \alpha'$		$y_0 = r \cos \delta \sin \alpha$
$z_0' = r' \sin \delta'$		$z_0 = r \sin \delta$

If we now transfer the origin of coördinates to the centre of the Moon, the axes remaining parallel, then the R. A. and Decl. of the Sun as seen from this new origin, will be the same as the R. A. and Decl. of the point Z, and therefore the coördinates of the Sun in this new system will be

$$x'_m = G \cos d \cos a$$
$$y'_m = G \cos d \sin a$$
$$z'_m = G \sin d$$

But these coördinates must evidently be equal respectively to the difference of the corresponding coördinates of the Sun and Moon the former system, that is

$$x'_m = x'_0 - x_0$$
$$y'_m = y'_0 - y_0$$
$$z'_m = z'_0 - z_0$$

or

$$\begin{aligned} G \cos d \cos a &= r' \cos \delta' \cos \alpha' - r \cos \delta \cos \alpha \\ G \cos d \sin a &= r' \cos \delta' \sin \alpha' - r \cos \delta \sin \alpha \\ G \sin d &= r' \sin \delta' - r \sin \delta \end{aligned} \qquad (46)$$

which determine a, d and G in terms of known quantities, but it is expedient to put these equations in a more convenient form for computation. Multiply the first by cos α' and the second by sin α' and add the products; also multiply the first by sin α' and the second by cos α' and subtract the first product from the second and we find

$$\begin{aligned} G \cos d \cos (a - \alpha') &= r' \cos \delta' - r \cos \delta \cos (\alpha - \alpha') \\ G \cos d \sin (a - \alpha') &= - r \cos \delta \sin (\alpha - \alpha') \\ G \sin d &= r' \sin \delta' - r \sin \delta \end{aligned} \tag{47}$$

Divide each of these by r' and put

$$\frac{G}{r'} = g \text{ and } \frac{r}{r'} = b$$

then they become

$$\begin{aligned} g \cos d \cos (a - \alpha') &= \cos \delta' - b \cos \delta \cos (\alpha - \alpha') \\ g \cos d \sin (a - \alpha') &= - b \cos \delta \sin (\alpha - \alpha') \\ g \sin d &= \sin \delta' - b \sin \delta \end{aligned} \tag{48}$$

Dividing the second of these by the first and the third by the second, we have

$$\tan (a - \alpha') = - \frac{b \cos \delta \sec \delta' \sin (\alpha - \alpha')}{1 - b \cos \delta \sec \delta' \cos (\alpha - \alpha')} \tag{49}$$

$$\tan d = - \frac{(\sin \delta' - b \sin \delta) \sin (a - \alpha')}{b \cos \delta \sin (\alpha - \alpha')} \tag{50}$$

and

$$g = \frac{\sin \delta' - b \sin \delta}{\sin d} \tag{51}$$

The quantity b is most easily computed as follows:

Let π = the Moon's equatorial horizontal parallax
π' = the Sun's " " "
π_0 = the Sun's mean horizontal parallax
and r_0 = the Sun's mean distance
then $r_0 \sin \pi_0 = r' \sin \pi'$

or expressing r' in terms of r_0, that is making $r_0 = 1$, we have

$$\sin \pi' = \frac{\sin \pi_0}{r'}$$

and also $r \sin \pi = r' \sin \pi'$

therefore

$$b = \frac{r}{r'} = \frac{\sin \pi'}{\sin \pi}$$

$$= \frac{\sin \pi_0}{r' \sin \pi} \tag{52}$$

in which r' and π are given in the ephemeris and π_0 is constant.

The formulæ for computing a, d and g are perfectly rigorous but as $(\alpha - \alpha')$ at the time of an eclipse can never exceed $1\frac{1}{2}°$, $a - \alpha_1$ is always less than $20''$, and b is about $\frac{1}{100}$, the following approximate formulæ will give the quantities with all the exactness required. At the time of an eclipse δ is nearly equal to δ' and we may write the arc for the sine and tangent of $\alpha - \alpha'$ and $a - \alpha'$ respectively and put cos $(\alpha - \alpha') = 1$, hence (49) becomes

$$(a - \alpha_1)'' = -\frac{b}{1-b} \cos \delta \sec \delta' \, (\alpha - \alpha')'' \qquad (53)$$

From the 1st and 3d of (48) we have approximately

$$g \cos d = \cos \delta' - b \cos \delta$$
$$g \sin d = \sin \delta' - b \sin \delta$$

Multiplying the first of these by sin δ' and the second by cos δ' and subtracting the second result from the first and also multiplying the first by cos δ' and the second by sin δ' and adding we have

$$g \sin (d - \delta') = -b \sin (\delta - \delta')$$

and $$g \cos (d - \delta') = 1 - b \cos (\delta - \delta')$$

whence $$\tan (d - \delta') = -\frac{b \sin (\delta - \delta')}{1 - b \cos (\delta - \delta')}$$

or approximateiy $$(d - \delta')'' = -\frac{b}{1-b} (\delta - \delta')'' \qquad (54)$$

and $$g = 1 - b \qquad (55)$$

and then $$G = r' g \qquad (56)$$

To Find the Co-ordinates of the Moon.

In the diagram take BX and ZY each equal to a quadrant, then OX, OY and OZ form a system of rectangular axes, having the origin at O, the centre of the Earth and the axis OZ parallel to MS the line joining the centres of the Moon and Sun and $BZ = PY = d$. The plane of xy is always at right angles to the axis of the shadow and is called the principal to fundamental plane of reference. The plane of yz is the plane of the declination circle through Z and the plane of xz is of course at right angles to the other two.

The axis of Z or OZ parallel to the axes of the shadow will be reckoned *positive* towards the Moon; the axis of y or OY, the intersection of the plane of the declination circle through Z with the principal plane, and will be taken as *positive* towards the north, and the axis of x or OX the intersection of the plane of

the equator with the principal plane, will be taken positive toward that point X whose R. A. is $90° + a$.

Let x, y, z be the coördinates of the Moon, and let XM', YM' and ZM' be joined by arcs of great circles, then we shall have

$$\begin{aligned} x &= r \cos XOM' = r \cos XM' \\ y &= r \cos YOM' = r \cos YM' \\ z &= r \cos ZOM' = r \cos ZM' \end{aligned}$$

From the spherical triangles XPM', YPM', and ZPM' we have by the fundamental formula of spherical trigonometry

$$\begin{aligned} \cos XM' &= \cos PM' \cos PX + \sin PM' \sin PX \cos M'PX \\ &= \sin \delta \cos 90° + \cos \delta \cos (90° + a - \alpha) \\ &= \cos \delta \sin (\alpha - a) \\ \cos YM' &= \cos PM' \cos PY + \sin PM' \sin PY \cos M'PY \\ &= \sin \delta \cos d + \cos \delta \sin d \cos (180° + a - \alpha) \\ &= \sin \delta \cos d - \cos \delta \sin d \cos (\alpha - a) \\ \cos ZM' &= \cos PM' \cos PZ + \sin PM' \sin PZ \cos M'PZ \\ &= \sin \delta \sin d + \cos \delta \cos d \cos (\alpha - a) \end{aligned}$$

Substituting these values in the above we have

$$\begin{aligned} x &= r \cos \delta \sin (\alpha - a) \\ y &= r [\sin \delta \cos d - \cos \delta \sin d \cos (\alpha - a)] \\ z &= r [\sin \delta \sin d + \cos \delta \cos d \cos (\alpha - a)] \end{aligned} \qquad (57)$$

Substituting $1 - 2 \sin^2 \frac{1}{2} (\alpha - a)$ for $\cos (\alpha - a)$ and reducing we obtain

$$\begin{aligned} x &= r \cos \delta \sin (\alpha - a) \\ y &= r \sin (\delta - d) + x \sin d \tan \tfrac{1}{2} (\alpha - a) \\ z &= r \cos (\delta - d) - x \cos d \tan \tfrac{1}{2} (\alpha - a) \end{aligned} \qquad (58)$$

which are more easily computed, or we may adapt (57) to logarithmic computation thus,

put $$\begin{aligned} c \sin C &= r \sin \delta \\ c \cos C &= r \cos \delta \cos (\alpha - a) \end{aligned}$$

then we shall have

$$\begin{aligned} x &= r \cos \delta \sin (\alpha - a) \\ y &= c \sin (C - d) \\ z &= c \cos (C - d) \end{aligned} \qquad (59)$$

To Find the Co-ordinates of the Place of Observation.

Let ξ, η and ζ be the coördinates of A, the place of observation

$\varphi = Ka$ the geographical latitude.
$\varphi' = KA'$ the reduced or geocentric latitude.
$\rho = OA$ the radius of the Earth for latitude φ.
and $\mu = VK$ the sidereal time.

then if we write ρ for r, φ' for δ and $\mu - a$ for $\alpha - a$ in (57) we shall evidently have the co-ordinates required, for the declination of A' is φ' and its longitude VK is μ, thus we have

$$\begin{aligned} \xi &= \rho \cos \varphi' \sin (\mu - a) \\ \eta &= \rho [\sin \varphi' \cos d - \cos \varphi' \sin d \cos (\mu - a)] \\ \zeta &= \rho [\sin \varphi' \sin d + \cos \varphi' \cos d \cos (\mu - a)] \end{aligned} \qquad (60)$$

which may be easily put in the form (58) or (59).

The angle $\mu - a$ or BPA' which is usually denoted by θ is the hour angle of the point Z for the meridian of the place of observation. If μ_1 be its value at Greenwich and λ the longitude of the place then we shall evidently have $\theta = (\mu - a) = \mu_1 - \lambda$.

To Find the Equation of Contact.

The fundamental plane always passes through the centre of the Earth and is perpendicular to the axis of the shadow; the plane through the place of observation and parallel to the fundamental plane is called the *parallel plane*. Now since the coördinates x and y of the Moon are also those of every point of the axis of the shadow, it is evident that with reference to the origin A, the coördinates of the axis of the shadow are $x - \xi$ and $y - \eta$, and if Δ denote the distance of A, the place of observation, from the axis of the shadow, we shall evidently have

$$\Delta^2 = (x - \xi)^2 + (y - \eta)^2 \qquad (61)$$

This equation can be put under another and a more useful form as follows:

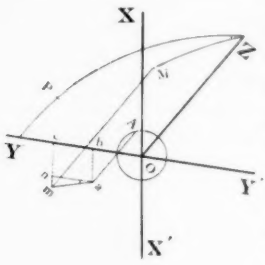
Let M be the Moon and A the place of observation, P the north pole and m and a the projections of M and A respectively on the fundamental plane, then the coördinates of M are

$$\begin{aligned} x &= cm \\ y &= Oc \end{aligned}$$

and of A,

$$\begin{aligned} \xi &= ab \\ \eta &= Ob \end{aligned}$$

Join m and a and draw an parallel to the axis of Y, then $\Delta = am$ which is the projection of the line (AM) joining the place of ob-



servation and the Moon's centre and the plane by which this line is projected contains the axis of the shadow and its intersection with the celestial sphere is a great circle passing through M and Z, therefore its projection am makes the same angle with OY, that MZ makes with the meridian PZ. Put the angle $PZM = nam = Q$ then in the right angled plane triangle amn we have

$$mn = mc - ab = x - \xi$$
$$an = Oc - Ob = y - \eta$$

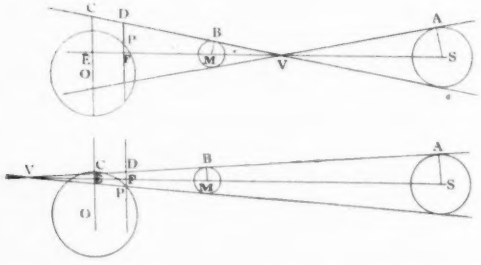
and

$$\Delta \sin Q = x - \xi$$
$$\Delta \cos Q = y - \eta \qquad (62)$$

The sum of the squares of which is identical with the preceding equation. The significance of the angle Q will be explained in a subsequent paper.

To Find the Radii of the Penumbral and Umbral Cones on the Fundamental and Parallel Planes.

Let CE be the radius of the shadow on the fnndamental and DF the radius on the parallel plane. V the vertex, M and S the centres of the Moon and Sun, and P the position of an observer on the Earth's surface.



Put h = apparent semi-diameter of the Sun at *mean* distance.
k = the ratio of the Moon's radius to the Earth's equatorial radius.
c = distance of the vertex V of the cone from the fundamental plane = VE.
z = distance between the planes = EF.
f = the angle of the cone = CVE.
l = radius of shadow on the fundamental plane = CE.
and L = radius of the shadow on the parallel plane = DF.

Taking the Sun's mean distance as unity, then at *this distance* we have

$$\text{Earth's radius} = \sin \pi_0$$
$$\text{Moon's radius} = k \sin \pi_0 = BM$$
and $$\text{Sun's radius} = \sin h = AS$$

Now in either figure we have

$$MV \sin f = BM = k \sin \pi_0$$
$$SV \sin f = AS = \sin h$$
then $$SV + MV = G = r'g, \text{ in the first figure}$$
and $$SV - MV = G = r'g, \text{ in the second figure}$$

therefore we have

$$r'g \sin f = \sin h \pm k \sin \pi_0$$
or
$$\sin f = \frac{\sin h \pm k \sin \pi_0}{r'g} \qquad (63)$$

where the plus sign corresponds to the penumbral and the minus sign to the umbral cone. The numerator of the second number of this equation is constant and may be computed once for all. Thus, according to Bessel, $h = 959''.788$ and from recent investigations of the solar parallax, $\pi_0 = 8''.81$* and $k = 0.272274$ therefore we have

$\log [\sin h + k \sin \pi_0] = 7.6688325$ for penumbral contact.
$\log [\sin h - k \sin \pi_0] = 7.6666628$ for umbral contact.

We also have $VM = k \operatorname{cosec} f$ and $EM = z$
therefore
$$c = z \pm k \operatorname{cosec} f \qquad (64)$$

in which the upper sign applies to the penumbra and the lower to the umbra, then we have

$$l = c \tan f = z \tan f \pm k \sec f$$
and
$$L = (c - \zeta) \tan f = l - \zeta \tan f \qquad (65)$$

For the penumbral cone L is always positive since $c > \zeta$, but for the umbral cone $c - \zeta$ is negative when the vertex V falls below the plane of the observer, therefore the criterion of a *total* eclipse is that L or $(c - \zeta) \tan f$ be a negative quantity. If, however,

* In the *American Ephemeris* two values of the Sun's mean equatorial horizontal parallax are used or in other words the solar system is regarded as elastic. This is decidedly wrong and not justified by any facts or theories in Astronomy. Until quite recently Encke's old value, viz, $8''.5776$, a value quite too small, was used in computing eclipses while a value of $8''.848$ was used in other portions. In the volumes of 1897 and 1898 two values are still employed, viz. $8''.800$ for eclipses and $8''.848$ elsewhere—an inconsistency not found in any other similar work but one which might be expected when we consider how the *American Ephemeris and Nautical Almanac* is prepared. A slight change in the Sun's parallax affects the duration and limits of visibility of both a partial and total or annular eclipse, but does not affect the line or path of central eclipse.

the vertex V in the case of the umbral cone falls *above* the plane of the observer, L will be positive which is the criterion of an *annular* eclipse.

For the sake of brevity, it is usual to put

$$\begin{aligned} i &= \tan f \\ l &= ic \\ L &= l - iz \end{aligned} \qquad (66)$$

The criterion of the beginning or ending of an eclipse for a *given place* is

$$\Delta = L$$

or by (61) and (66)

$$(x - \xi)^2 + (y - \eta)^2 = (l - iz)^2 \qquad (67)$$

which, however, is more conveniently expressed by the following two equations in accordance with (62)

$$\begin{aligned} (l - iz) \sin Q &= x - \xi \\ (l - iz) \cos Q &= y - \eta \end{aligned} \qquad (68)$$

Equation (67) or its equivalent (68) is the fundamental equation in the theory of eclipses and its complete discussion furnishes all the circumstances relating to the duration and limits of visibility of these phenomena. The quantities x, y, l, $\tan f$, $\sin d$, $\cos d$ and μ, or $(\alpha - a)$ are independent of the place of observation and can be computed for any dates at the prime meridian. They are computed for several consecutive hours preceding and following conjunction, then interpolated to every ten minutes and tabulated under the head of Besselian Elements. The logarithms of the variations of x and y per minute are also given. These elements furnish the data for the solution of (68) which will be presented in subsequent papers.

(TO BE CONTINUED).

PROBLEMS.

22. Find the least possible inclination to the horizon of the line joining the cusps of the Moon.

23. Can a star be found whose real position is unaffected by parallax, refraction and aberration?

24. Given the synodic period of the Moon S, and the length of the sidereal year T_s, find the length of the sidereal period of the Moon.

25. The Moon was observed to rise at the same sidereal time on two successive nights and the inclination of its orbit to the equator was θ, show that sin lat. of the place $= \cos \theta$.

26. To what extent does the diurnal rotation of the Earth affect the duration of a total eclipse of the Sun, at a place on the Earth's equator?

27. If f and f' denote the semi-vertical angles of the umbral and penumbral cones respectively and d the Sun's apparent semi-diameter show that $2 \tan d = \tan f + \tan f'$.

EVENINGS WITH THE STARS.

MARY PROCTOR.

Many delightful evenings, may be spent in observing the starry heavens, if only the observer goes properly to work. Let us suppose that he is provided with a good star-atlas, (I would recommend "Half-Hours with the Stars," published by Putnam's Sons, New York), and an opera glass, and that he is about to commence his astronomical studies. Let us first obtain a general outline of the constellations for each month, and then take three, for instance, for special observation. This month the three constellations will be Ursa Major, Ursa Minor and Taurus.

General Outline.

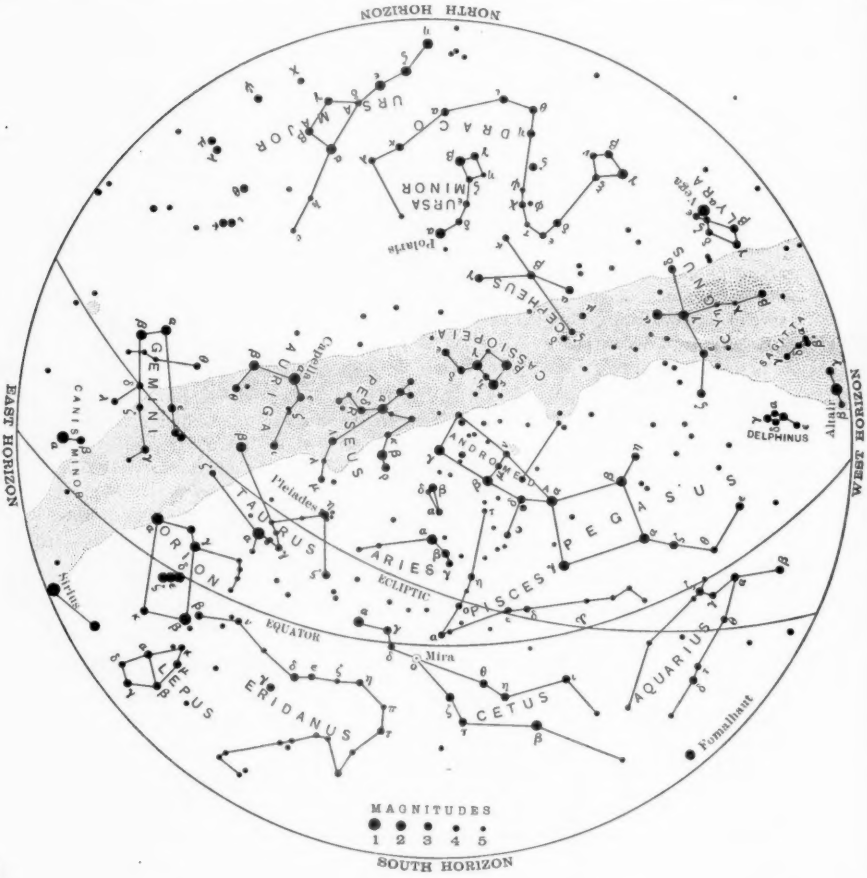
Rising above the northeast horizon is (*Ursa Major*), the Great Bear; due north is (*Ursa Minor*), the Little Bear, with the stars of (*Draco*), the Dragon winding below the Little Bear towards the west. Above is King Cepheus, and above him (*Cassiopeia*) his queen, their daughter, the Chained Lady, (*Andromeda*) being nearly overhead. Towards the southwest, is (*Aquarius*), the Water Bearer, close by the Winged Horse (*Pegasus*), south of which is (*Pisces*), the Fishes. In the south, is (*Cetus*), the Whale, Phœnix and Eridanus. Almost overhead, (*Aries*) the Ram, whilst towards the east, are (*Gemini*), the Twins, (*Taurus*), the Bull, Orion, (*Lepus*), the Hare, and (*Canis Major*) the Great Dog, and (*Columba*), the Dove, which are rising in the southeast.

Ursa Major.

The first step in studying the stars is to become acquainted with the renowned group of the Great Dipper, as it is called, in Ursa Major. There are many features of interest in this group of stars, and the beginner should first learn to identify the "seven" stars, and then the "two" stars, generally called the "pointers" because they point to the Pole star. First, note the three stars in the handle of the dipper, curving into two of the stars forming the back of the dipper. Now the remaining two stars, forming the front of the dipper, are the "pointers." Continue the line from these stars upward from the dipper, and you come to the Pole star, the first bright star on the way, so you cannot fail to place it correctly. After observing the Dipper with the unaided eye, turn an opera-glass towards it, and ten times as many stars will be seen. If you are the fortunate owner of a telescope, hundreds of stars will be revealed in this small group, and through such an instrument as the one at the Lick Observatory, the number would have to be reckoned in thousands.

Professor Young tells us, in his *Lessons on Astronomy*, that the dimensions of the Dipper furnish a convenient scale of angular measure. From Alpha to

Beta (the "Pointers,") is 5°; from Alpha to Eta, (the star at the extremity of the Dipper Handle,) is 26°. The star Zeta (or Mizar,) at the bend of the handle, is easily recognized by the little star *Alcor* near it. Mizar is a beautiful double star, composed of two stars, shining with a white, and a pale green light. These stars are of the second and fourth magnitude, and they can be easily observed with a small telescope, and even with a very powerful field glass. The small star Alcor can



THE CONSTELLATIONS AT 9 P. M., DEC. 1, 1896.

be readily seen with the unaided eye, but must not be mistaken for the component of Mizar, for in the magnifying power of a telescope, Alcor is seen removed along way from this star. In *Astronomy with an Opera Glass*, Garrett P. Serviss, recommends the observer, to sweep along the whole length of the Dipper's handle

and many fine fields of stars will be discovered. Then look at the star Alpha, in the outer edge of the bowl nearest to the Pole-star, there is a faint star of about the eighth magnitude, near it, in the direction of Beta. It is of a reddish color. The star Alpha is approaching the Earth with an average speed of somewhere about 40 miles a second, and it has been observed "to alternate in color from red to yellow, in a period of 54½ days. The star is under no suspicion of varying in light."—(*System of the Stars*, p. 147, Agnes M. Clerke).

Near the second "pointer," is a spot of faint light, described by Sir John Herschel, as "a most extraordinary object," a large, uniform nebulous disc, quite round, very bright, not sharply defined, but yet very suddenly fading away to darkness. At Parsonstown, in 1848, two stars were perceived in the interior, each surrounded by a dark space encroached upon by nebulous whorls, and the object received the name of the "Owl Nebula," from the appearance of two great eyes thus presented."—(*System of the Stars*, p. 256).

The seven stars in the Great Dipper, are in reality seven splendid suns, probably very much larger than our Sun, and glowing with intense lustre. Iron, sodium, magnesium and other well known elements, exist in the atmospheres of these stars, and their massive globes raging with fiery heat, rush through the depths of space, with inconceivable speed. Five of the stars are receding from us at the rate of seventeen miles per second, the other two are travelling in an opposite direction. It is certain that these two do not belong to the same system as the other five. Thirty-six thousand years hence, the seven stars of the Great Dipper will have dissolved partnership, and its appearance will have changed. The handle of the Dipper will be bent and its rim out of place, for the reason that five stars will have drifted in one direction and two in another. During countless ages the stars which seem so steadfast have been rushing onward through space. There are stars travelling in "family parties," as Miss Clerke quaintly expresses it, colonies of stars of a friendly tendency drifting together others less friendly drifting apart. Despite the fact, that each star thus urging its way through space, is an enormous mass of glowing vapor, yet the most perfect order and harmony prevails in the star-depths.

Groombridge 1830, the Runaway Star.

Between the constellation of Ursa Major and Ursa Minor, there is a star of the sixth or seventh magnitude, and therefore invisible to the unaided eye. "It is known as Groombridge 1830 and though small, it is in one respect one of the most remarkable stars in the northern hemisphere. It is at least four or five times as far from the Earth as the star 61 Cygni and travels at the rate of two hundred miles a second In ten minutes it has travelled 120,000 miles. If our Earth moved equally fast the journey around the Sun would be accomplished in a month, instead of the year which is now required. The velocity of Groombridge 1830 is no mere spasmodic effort; with a stately uniformity, worthy of the dignity of a majestic sun, it sweeps along, alike inflexible in the direction of its motion and in the velocity with which its journey is performed."—(*The Story of the Heavens*, p 425, Robert S. Ball). But there are now two other "runaway" stars outrunning even Groombridge. Arcturus moves palpably through the heavens at the rate of 375 miles a second, and the velocity of Mu Cassiopeia is 363 miles a second. "Flying stars" can then no longer be regarded as intruders into stellar society. Whether or not they belong to it for better or for worse, they evidently form at present an important part of its mechanism."—*System of the Stars*, p. 345.

Polaris, the Pole Star.

When Shakespeare wrote the familiar lines: "I am as constant as the Northern Star, of whose true fixed and resting quality there is no fellow in the firmament," he was not aware of the fact that Polaris was anything but fixed. It is urging its way through space at the rate of about forty-six miles a second, and in about nine thousand years Alpha Centauri will take its place as our guide. Polaris has held its post of honor for over a thousand years, and it was preceded in office by Thuban of the Dragon.

Ursa Minor, the Little Bear.

This constellation, though not remarkable in its appearance and containing but few bright stars, is nevertheless justly distinguished on account of its position in the heavens. The stars in this group being situated near the celestial Pole appear to revolve about it very slowly and in circles so small as never to descend below the horizon. Its leading star is Polaris, the North Polar star. It is of the third magnitude and situated a little less than a degree and a quarter from the true Pole of the heavens, on that side of it which is towards Cassiopeia and opposite to Ursa Major. "The pole-star is a famous double but its minute companion can only be seen with a telescope. As so often happens, however, it has another companion for the opera-glass, and this latter is sufficiently close and small to make an interesting test for an inexperienced observer armed with a glass of small power. It must be looked for pretty close to the rays of the large star, with such a glass. It is of the seventh magnitude. With a large field-glass several smaller companions may be seen and a very excellent glass may show an 8th magnitude star almost hidden in the rays of the 7th magnitude companion. The star Beta, which is also called Kochab, has a pair of faint stars nearly north of it, about one degree distant. With a small glass these may appear as a single star, but a stronger glass will show them separately."—(*Astronomy with an Opera-Glass*, p. 27, Garrett P. Serviss.) Ursa Minor contains twenty-four stars including three of the third magnitude and four of the fourth. The seven principal stars form a figure resembling that of the Great Dipper, only that the Dipper is reversed and about one-half as large as the one in that constellation. The first star in the handle is the polar star, around which the rest constantly revolve. The two last in the bowl of the Dipper, corresponding to the Pointers in the Great Bear, are of the third magnitude and situated about 15° from the pole. The brightest of them is called Kochab, and it may be easily known by its being the brightest and middle one of three conspicuous stars forming a row, one of which is about 2° and the other 3° from Kochab. The two brightest of these are situated about 3° apart and are called the *Guards* or *Pointers* of Ursa Minor. Of the four stars which form the bowl of the Dipper, one is so small as hardly to be seen. They lie in a direction towards Gamma in Cepheus.

Legend.

According to Grecian mythology Ursa Major and Ursa Minor are the nymph Calisto and her son Arcas who were transformed into bears by the imperious Juno and afterwards placed among the stars by Jupiter. The unbear-like length of the creatures' tails is explained by the statement that they stretched as Jupiter lifted them to the sky. Calisto was a native of the city of Helice in Achaia, a district near the bay of Corinth, hence the Greater Bear is sometimes called Helice.

Taurus, the Bull.

In the old star-map Taurus, the Bull, is represented as if in an attitude of rage, and about to attack Orion. Only the head and shoulders of the animal are to be

seen, but these are so distinctly marked that they cannot be mistaken. The constellation is situated between Perseus and Auriga on the north, Gemini on the east, Orion and Eridanus on the south, and Aries on the west, having a mean declination of 16° N. It contains 141 visible stars including two remarkable clusters called the Pleiades and Hyades. The first is on the shoulder and the latter is in the face of the Bull. It is very easy to identify this constellation either by the Pleiades or by the bright and somewhat ruddy star Aldebaran, the eye of the Bull.

ALDEBARAN.

Aldebaran is a first magnitude star giving three times as much light as the pole star. The redness of its light is a very interesting phenomenon. Compare its color with the deep orange hue of Betelgeuse, or Alpha Orionis, or glance from Aldebaran to the brilliant white star Rigel in the foot of Orion, and turning the eye back again to Aldebaran the peculiar rosy red color of the latter is readily perceived. The spectrum of Aldebaran exhibits the lines corresponding to hydrogen, and no less than eight metals, sodium, magnesium, iron, bismuth, tellurium, antimony and mercury, are proved to exist in its composition. Light takes 28 years in coming to the Earth from this star, according to the measurements made by Dr. Elkin at Yale, and it is receding from the Earth at the rate of about 30 miles a second. Aldebaran is a sun glowing with its own light, and is a body intensely heated like the Sun. The name Aldebaran is of Arabic origin, and takes its name from two words which signify "He went before or led the way," alluding to that period in astronomy when this star led up the starry host from the vernal equinox.

None of the other larger stars in Taurus present any features of interest in small telescopes. Between the horns of the Bull when observed with an opera-glass, a broken stream of minute stars may be seen but a still better sight can be obtained with a fine field-glass. "With such a glass their appearance almost makes one suspect that Virgil had a poetic prevision of the wonders yet to be revealed by the telescope when he wrote, as rendered by Dryden:

"When with his golden horns in full career
The Bull beats down the barriers of the year."

Below the tips of the horns and over Orion's head there are also rich clusters of stars. The two stars in the tips of the horns are both interesting, each in a different way. The upper and brighter one of the two is called El Nath (Beta). It is a singularly white star. This quality of its light becomes conspicuous when it is looked at with a glass. The most inexperienced observer will hardly fail to be impressed by the pure whiteness of El Nath, in comparison with which he will find that many of the stars he had supposed to be white show a decided tinge of color. The star in the tip of the right or southern horn, Zeta, is remarkable, not on its own account, but because it serves as a pointer to a famous nebula, the discovery of which led Messier to form his catalogue of nebulæ. This is sometimes called the "Crab Nebula," from the long sprays of nebulous matter which were seen surrounding it with Lord Rosse's great telescope.—(*Astronomy with an Opera Glass*, pp. 96, 96).

THE HYADES.

The Hyades are situated 10° S. E. of the Pleiades, in the face of the Bull, and may be readily distinguished by means of five stars so placed as to form the letter V. The most brilliant star is on the left, in the top of the letter, and called Aldebaran. The Hyades show some fine fields of stars, when observed with a small

telescope. Serviss tells us that the inexperienced observer is certain to be surprised by the display of stars which an opera glass brings to view in the Hyades. An illustration, on page 99 of his book on *Astronomy with an Opera Glass*, gives some notion of their appearance as seen with a large field glass.

Legend of the Bull.

According to Grecian mythology the Bull is the animal which bore Europa over the seas to that country which derived from her its name. She was the daughter of Agenor and Princess of Phœnicia, and was beloved by Jupiter. The god assumed the appearance of a snow white bull and mingling with the herds of Agenor, attracted the attention of Europa, who was gathering flowers in the meadows with her female attendants. Caressing the animal she finally ventured to sit on its back when instantly the bull hurried towards the shore and plunging into the waves crossed the sea with Europa, and arrived safely at Crete.

The Pleiades.

The group of stars, called the Pleiades, is one of the most interesting objects in the heavens. In former times, these stars, were thought to exert important influence on the weather, probably because when the Sun was in Taurus which then corresponded with the end of April, it was a time when all nature seemed to spring into activity. In every age and country, they have been an object of admiration and wonder. They are referred to in the Holy Writ, in the well known passage: "Can'st thou bind the sweet influences of the Pleiades, or loose the bands of Orion." It is fabled, that there were once seven Pleiades visible to the unaided eye, but that one called the lost Pleiad has faded from view. The seven stars were supposed to be the seven daughters of Atlas, whose names were Merope, Alcyone, Celæno, Electra, Taygeta, Asterope, and Maia. The lost Pleiad is accounted for, by the fact, that Merope married a mortal and, for that reason, her light is dim: whilst others say, that this was Electra, who hid her face at the burning of Troy. With good eyesight, however, not only can the original seven Pleiads be distinctly seen, but several others. A few observers have even counted as many as fourteen Pleiads. With the most powerful field-glass, Garrett P. Serviss tells us, that an immense number of stars are revealed, whilst with a small telescope, this group becomes a very beautiful and amazing object. Seen with a field glass, Alcyone is the most conspicuous star, and to the left or east are Atlas and Pleione, who were the father and mother of the seven sisters. It is not easy to see Pleione without a glass, but Atlas is plainly visible to the unaided eye. The Pleiades are literally a flight of suns, drifting together in one direction, and we see, as Miss Clerke expresses it, "the unique phenomenon, of the transport in block across the sphere of a couple of thousand congregated suns." Six stars, however, according to Bessel's observations, are lagging behind, whilst two are hurrying on in front. There are "battalions of stars—flying synods of worlds—regardless, as it were, of the erratic flittings of the causal surrounding crowd, marching in widely extended ranks, by a concerted plan, along a prescribed track, under orders sealed perhaps forever to human intelligence, amid seeming confusion, order and purpose, by glimpses reveal themselves.—(*Systems of the Stars*, p. 346.)

Distance of the Pleiades.

We find the distance of the Pleiades to be nearly 1,500 billions of miles, or 250 light years from the Earth. In other words, a ray of light travelling at the rate of 186,500 miles a second would take no less than 250 years in crossing this vast abyss.

PHOTOGRAPH OF THE PLEIADES.

When Paul and Prosper Henry turned their great photographic telescope, upon the Pleiades still greater wonders were revealed. In place of a few hundred stars, 2,326 showed their presence closely connected with nebulous particles of misty light clinging around the brighter stars and weaving a delicate tracery in the spaces between. There is an undoubted connection between the nebulous masses and the stars, for in another photograph taken in 1888 the greater part of the constellation "was seen veiled in nebulous mist, in some places lying in heavy folds and wreaths like a veil of gauze, in others faint and indistinct. A long streak of nebulous matter, on which eight or nine stars were strung like beads on a chain, irresistably suggest an intimate connection between the stars and nebulæ, making Tennyson's picturesque description all the more life-like:

"Many a night I saw the Pleiades rising through the mellow shade,
Glitter like a swarm of fire-flies tangled in a silver braid."

(For further information with regard to the Pleiades read pp. 100 to 105 in *Astronomy with an Opera Glass*, by Garrett P. Serviss, and Chapter XV in *The System of the Stars*, by Agnes M. Clerke).

PLANET NOTES FOR DECEMBER.

H. C. WILSON.

Mercury will be evening planet during December but will not be visible until toward the end of the month. He is now almost directly behind the Sun but will move eastward slowly emerging from the Solar rays. The low altitude of the planet in our latitude will preclude the possibility of making observations of any value during this month. Mr. Lowell announced in October, from his private Observatory at Flagstaff, Ariz., that Mercury rotates upon its axis once in the period of its revolution about the Sun, thus keeping the same side always toward that body. This agrees with the conclusion reached by the Italian astronomer Schiaparelli several years ago. Mr. Lowell also concludes from his observations that Mercury is not veiled in a dense atmosphere. Astronomers in general, however, will be very slow about accepting these conclusions. The details of surface-marking depended upon are so delicate and diffuse as to be well-nigh impossible of certain identification.

Venus is now so brilliant just after sunset that hardly any one can have failed to notice her near the southwestern horizon. Toward the end of December her position will be considerably more favorable because of the planet's northerly motion in declination. An interesting article on the surface-markings and rotation period of Venus, by Mr. Lowell, will be found in this number of POPULAR ASTRONOMY.

Mars will be at opposition on Dec. 10, crossing the meridian then a few minutes before midnight. The planet will then be at its greatest altitude and so most favorably situated for observation. It will be nearest to the Earth on Dec. 4, nearly a week before opposition, when the distance will be a little more than 60,000,000 miles. The greatest apparent diameter of Mars' disk at this time will be 18″.0. The reader will be especially interested in the drawings of Mars by Mr. Lowell, and Mr. Douglass given in this number. At Northfield the weather has been so wretched during November that no attempts could be made

to observe the planet. Its brightness and orange-red color make the planet so conspicuous that none can fail to recognize it. At nine o'clock in the evening Mars is seen about half way from the east horizon to the zenith, among the stars of Taurus.

Jupiter is morning planet, near the meridian at six o'clock, an inconvenient hour for the observer, especially in winter.

Saturn and *Uranus* are behind the Sun. They will be in conjunction with each other on December 28.

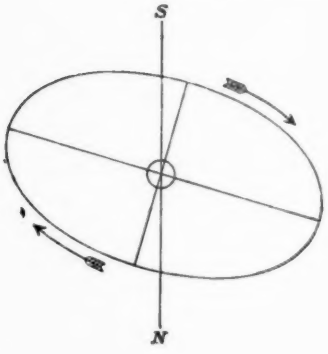
Neptune will be at opposition on the morning of Dec. 10, twenty hours before Mars. The two planets will be in conjunction on the evening of Dec. 12 when Neptune will be 4° 8′, or eight diameters of the Moon, north of Mars. Both are moving westward, Mars at the rate of 1ᵐ 40ˢ, Neptune at the rate of 7ˢ per day.

Ephhemeris for Physical Observations of Mars.

(From *Monthly Notices, R. A. S.*, April, 1896.]

Greenwich Noon.	Position Angle of Axis. °	Areographic Latitude Center of Disk. °	Areographic Longitude Central Meridian. °	Passage of Zero Meridian. (Cen. St'd Time.) h m
Dec. 2	330.23	— 1.48	140.20	9 1 P. M.
4	329.88	1.90	122.62	10 13 "
6	329.53	2.32	105.06	11 25 "
8	329.19	2.74	87.50	12 1 A. M.
10	328.85	3.16	69.95	1 13 "
12	328.51	3.57	52.39	2 25 "
14	328.19	3.97	34.82	3 37 "
16	327.88	4.36	17.24	4 49 "
18	327.58	4.73	359.63	6 1 "
20	327.30	5.18	342.00	7 14 "
22	327.04	5.41	324.34	8 26 "
24	326.79	5.72	306.65	9 39 "
26	326.57	6.00	288.92	10 51 "
28	326.37	6.25	271.15	12 4 P. M.
30	326.19	— 6.48	253.34	1 17 "

Elongations of the Satellites of Neptune.



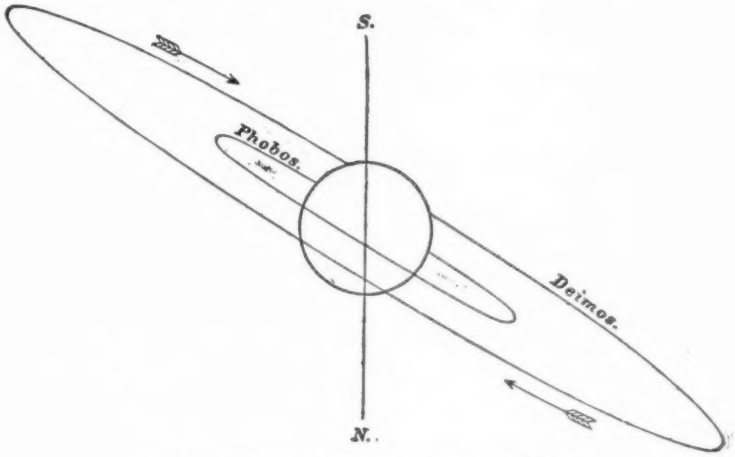
East.

Dec.	3	9.1 P. M.
	9	6.2 "
	15	3.3 "
	21	0.4 "
	27	10.4 A. M.

West.

Dec.	6	7.6 P. M.
	12	4.7 "
	18	1.8 "
	24	10.9 A. M.
	30	8.0 "

The Satellites of Mars.



APPARENT ORBITS OF THE SATELLITES OF MARS.

PHOBOS.

		h	m			
Dec.	1	6	12	P. M.		W
	1	10	2	"		E
	2	5	9	"		W
	2	8	59	"		E
	3	4	7	"		W
	3	7	57	"		E
	3	11	47	"		W
	4	6	54	"		E
	4	10	44	"		W
	5	5	51	"		E
	5	9	41	"		W
	6	4	48	"		E
	6	8	38	"		W
	7	3	46	"		E
	7	7	36	"		W
	7	11	26	"		E
	8	6	33	"		W
	8	10	23	"		E
	9	5	30	"		W
	9	9	20	"		E
	10	4	27	"		W
	10	8	17	"		E
	11	3	24	"		W
	11	7	14	"		E
	11	11	4	"		W
	12	6	12	"		E
	12	10	2	"		W
	13	5	8	"		E
	13	8	58	"		W
	14	4	6	"		E
	14	7	56	"		W
	14	11	46	"		E
	15	6	53	"		W
	15	10	43	"		E
	16	5	50	"		W

PHOBOS, CON'T.

		h	m			
Dec.	16	9	40	P. M.		E
	17	4	47	"		W
	17	8	37	"		E
	18	3	45	"		W
	18	7	35	"		E
	18	11	25	"		W
	19	6	32	"		E
	19	10	22	"		W
	20	5	29	"		E
	20	9	19	"		W
	21	4	26	"		E
	21	8	16	"		W
	22	3	24	"		E
	22	7	14	"		W
	22	11	4	"		E
	23	6	11	"		W
	23	10	1	"		E
	24	5	8	"		W
	24	8	58	"		E
	25	4	5	"		W
	25	7	55	"		E
	25	11	45	"		W
	26	6	53	"		E
	26	10	43	"		W
	27	5	53	"		E
	27	9	43	"		W
	28	4	48	"		E
	28	8	38	"		W
	29	3	45	"		E
	29	7	35	"		W
	29	11	25	"		E
	30	6	32	"		W
	30	10	22	"		E
	31	5	30	"		W
	31	9	20	"		E

DEIMOS.

		h	m			
Dec.	1	4	11	P. M.		W
	2	10	27	"		W
	3	1	35	"		E
	4	7	51	"		E
	5	10	58	"		W
	6	2	6	A. M.		E
	6	5	14	P. M.		W
	7	11	30	"		W
	8	2	38	"		E
	9	8	54	"		E
	10	12	2	"		W
	11	6	17	"		W
	13	12	33	A. M.		W
	13	3	41	P. M.		E
	14	9	57	"		E
	15	1	5	"		W
	16	7	21	"		W
	18	1	37	A. M.		W
	18	4	45	P. M.		E
	19	11	1	"		E
	20	12	9	"		W
	21	8	25	"		W
	23	2	41	A. M.		W
	23	5	50	P. M.		E
	25	12	6	A. M.		E
	25	3	14	P. M.		W
	26	9	30	"		W
	27	12	39	"		E
	28	6	55	"		E
	30	1	12	A. M.		E
	30	4	20	P. M.		W
	31	10	37	"		W

Occultations Visible at Washington.

Date 1896.	Star's Name.	Magnitude.	IMMERSION. Washington M. T.	IMMERSION. Angle f'm N pt.	EMERSION. Washington M. T.	EMERSION. Angle f'm N pt.	Duration.
			h m	°	h m	°	h m
Dec. 8	9 Capricorni	4.1	7 35	350	7 59	308	0 24
14	101 Piscium	6.3	6 19	54	7 45	232	1 26
15	26 Arietis	6.0	12 32	102	13 38	227	1 6
20	37 Geminorum	6.3	8 28	131	9 24	233	0 56
24	48 Leonis	5.5	13 12	75	14 0	355	0 48
24	35 Sextantis	6.2	20 2	165	20 52	263	0 50

VARIABLE STARS.

I. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

1897.	d	h
Jan.	0	13
	5	12
	10	12
	15	12
	20	11
	22	23
	25	11
	27	23
	30	11

ALGOL.

Jan.	4	0
	6	21
	9	18
	12	15
	15	12

ALGOL CONT.

1897.	d	h
Jan.	18	8
	26	23
	29	20

λ TAURI.

Jan.	15	20
	19	19
	23	18
	27	17
	31	16

R CANIS MAJ.

Jan.	0	16
	1	19
	2	22
	6	8
	7	11

R CANIS CONT.

1897.	d	h
Jan.	8	15
	9	18
	10	21
	14	7
	15	10
	16	13
	17	17
	18	20
	23	9
	24	12
	25	15
	26	19
	27	22
	31	8

S CANCRI.

Jan.	12	15
	31	14

S VELORUM.

1897.	d	h
Jan.	4	9

δ LIBRAE.

Jan.	1	23
	6	15
	8	23
	13	14
	15	22
	22	22
	29	21

U CORONAE

Jan.	5	21
	19	17
	26	14

W DELPHINI.

Jan.	14	11
	19	7

Maxima and Minima of Long Period Variables.

MAXIMA.

February 1897.

			Day
103	T	Andromedæ	6
1582	S	Tauri	18
1850	S	Pictoris	2:
2583	L_2	Puppis	17
3264	W	Cancri	24:
3825	R	Ursæ Maj.	7
4225	X	Centauri	20:
4816	V	Virginis	28
5249	V	Libræ	10:
5338	U	Bootis	15
5617	U	Libræ	3
5758	X	Herculis	2
5795	W	Scorpii	3

MAXIMA CONT.

February 1897.

			Day
5903	Y	Scorpii	15:
5950	W	Herculis	9
6207	Z	Ophiuchi	26
6849	R	Aquilæ	18
7106	S	Vulpeculæ	28
7120	χ	Cygni	23
7257	R	Sagittæ	16
7448	W	Aquarii	17
7754	W	Cygni	21
8373	S	Pegasi	2

MINIMA.

February 1897.

			Day
845	R	Ceti	24
1222	R	Persei	1
1717	V	Tauri	27
2625	V	Geminorum	14
2676	U	Monocerotis	14
2976	V	Cancri	26
3477	R	Leonis min	18
4511	T	Virginis	11
5095	R	Centauri	27:
5583	X	Libræ	18
5887	V	Ophiuchi	8:
6794	R	Lyræ	14
6943	T	Sagittæ	26:
7106	S	Vulpeculæ	2
7577	X	Capricorni	25:

The above ephemeris was computed for POPULAR ASTRONOMY directly from the elements given in Chandler's Third Catalogue. For the Algol type stars I have given all the minima which occur in the night hours in American and European longitudes, when the star is above the horizon.

The new Algol star, 3416 S Velorum has not been included previously. Its position for 1900 is

R. A. $9^h\ 29^m\ 27^s$ Decl. $-44°\ 45'.9$

It varies from 7.8 to 9.3 magnitude, with a period of $5^d\ 22^h\ 24.35^m$. The following particulars are given in the notes to the Third Catalogue—"Discovered by Woods, 1894; confirmed by Roberts. Light oscillations occupy about one-tenth of period, or 15.2 hours. Stationary at minimum for 6.5 hours"

In the long period ephemeris all the stars are given whose periods are greater than 40 days. Dr. Chandler's ephemeris for 1897 has appeared in *Astronomical Journal* No. 387. It contains only stars having periods of more than four months. In several cases my date is one day later than Chandler's, as I have uniformly called 27.5, 28, while he has called it 27. In all other cases the dates agree.

The *Astrophysical Journal* for October contains a spirited article by Professor Roberts on the accuracy attainable by eye estimates of magnitude. It is in reply to a paper by Professor Pickering in the April number of the same journal, claiming greater accuracy for photometer measures. Professor Roberts uses a reversing prism before the eyepiece, and observes in both the direct and the reversed position, thus eliminating the effect of change of position of the stars due to varying hour-angle. He gives details of one night's work upon the variable L 5861, whose period is $7^h\ 16^m$ and range of variation only 0.4 of a magnitude. When corrected for systematic errors, the mean discordance of a single observation (the mean of 10 comparisons, 5 direct and 5 reversed) was only 0.037 mag. In Professor Pickering's article, the mean deviation of a single observation (the mean of 8 photometric settings) is given as 0.08 mag. for T Andromedæ. For Z Herculis the same quantity is 0.04 mag., the mean of 16 settings. Judging from these results the advantage in accuracy seems to lie with visual estimates.

R and S Scorpii.—Miss O'Halloran's interesting observations of "N"* and S Scorpii, in the November number, call for two comments. The first star is not "N" but *R*. In full the stars are as follows:

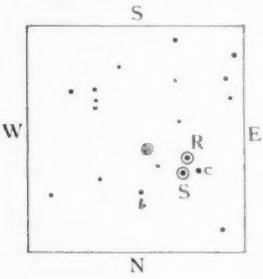
	Place for 1900		Mag.		Per.
	R. A.	Decl.	Max.	Min.	d
	h m s	° ′			
5830 R Scorpii	16 11 41	−22 41.9	9.4	10.5 13	224.5 Per. inecq.
5831 S "	16 11 42	−22 39.0	9.1	10.5 13	176.7

The dates of maximum by these elements (from Chandler's Third Catalogue) are the same as given by Miss O'Halloran; for R, June 2, for S, June 9: but if we examine the observations before us for confirmation of these dates, we find, unfortunately, that they yield no definite results, since, with one exception, variable is compared with variable. If we have learned anything in the past campaign it is that our standards of value should be constant. Use only unvarying stars for comparison, and if you find that your comparison star is varying, discard it and select a better one.

The accompanying little chart, about 40′ square, shows the position of the

* This "*N*" should have been *R*. It was so in Miss O'Halloran's copy. It was proof reader's error.

R. & S Scorpii
From Klein's Star Atlas



two variables relative to the cluster 80 Messier. Chandler gives the magnitude of the comparison star *c* as 9.4. The past maxima as observed here were:

R, 1896, June 4, 10.3 mag.
S, " June 26, 9.8 "

The elements give the following dates for the maxima in 1897:

R, Jan. 13 and Aug. 26.
S, May 28 and Nov. 21.

J. A. PARKHURST.

COMET NOTES.

A new comet, *f* 1896, was discovered by Mr. C. D. Perrine, at Lick Observatory, Nov. 2. The discoverer's account and elements by himself and Professor Hussey follow. There has been no opportunity to look up the comet at Northfield, on account of bad weather and moonlight.

Comet *f* 1896.—This comet was discovered by the writer on the evening of November 2. At the time of discovery it was in the constellation *Vulpecula*. At $19^h\ 13^m\ 3^s$ Gr. M. T. its position was R. A. $20^h\ 21^m\ 36^s.33$, Decl. $+\ 25°\ 6'\ 39''.8$ It was found to be moving southward about 50′ and westward nearly 2^m per day.

Observations were secured here the two nights following discovery and from these three observations Professor Hussey and I have deduced the following system of parabolic elements:

T = 1897 January 18.6072 Gr. M. T.
ω = 133° 8′ 35″ }
Ω = 78 33 48 } Mean ecliptic and equinox of 1896.0.
i = 145 52 56 }
q = 1.5441

Residuals—O − C, $\Delta\lambda \cos\beta - 5''$, $\Delta\beta + 1''$.

With the exception of ω these elements agree closely with those of Comet 1847 IV; there is a difference of some 78°, however, in ω.

The comet is small being only about 2′ in diameter and is not brighter than a star of 10½ magnitude. It has a decided central condensation and a stellar nucleus can be detected of about 13th magnitude. No traces of a tail are to be seen with the 12-inch telescope.

At the time of discovery its distance from the Earth was about 140 million miles. The distance is slowly increasing and in consequence the comet is becoming fainter.

C. D. PERRINE.

Lick Observatory, November 9, 1896.

Elements and Ephemeris of Comet *f* 1896.—From my observations of this comet on November 2, 6 and 11, the following system of parabolic elements is deduced:

$T = 1897$ February 8.15286

$\omega = 172\ 37\ 36$
$\Omega = 86\ 28\ 00$ } Mean Ecliptic and Equinox of 1896.0
$i = 146\ 8\ 42$
$\log q = 0.024318$

Residuals for the middle place:

$O - C$	$\Delta\lambda' \cos \beta'$	$-4''.0$
	$\Delta\beta'$	$-1\ .0$

The elements involving the time and distance of perihelion passage must be considered as somewhat uncertain.

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1896.	App. α.	App. δ.	log r.	log Δ.	Light.
	h m s	° ′			
Nov. 23.5	19 57 20	+ 10 26.1	0.2092	0.2424	1.00
25.5	56 6	9 17.8	0.2031	0.2484	1.00
27.5	55 1	8 12.2	0.1970	0.2543	1.00
29.5	54 3	7 8.9			
Dec. 1.5	53 11	6 8.0	0.1847	0.2655	1.00
3.5	52 26	5 9.3			
5.5	51 46	4 12.8	0.1722	0.2760	0.99
7.5	51 12	3 18.2			
9.5	50 42	2 25.4	0.1596	0.2856	0.98
11.5	50 16	1 34.4	0.1533	0.2900	0.97
13.5	19 49 54	+ 0 44.9	0.1470	0.2941	0.96

(The brightness at discovery is taken as unity.)

C. D. PERRINE.

Lick Observatory, November 16, 1896.

Comet *d* 1896 (Giacobini) appears to have been observed at but few places. The orbit turns out to be elliptic and of short period, so that, although the comet is very faint and uninteresting in appearance, observations of its position are highly important. It can only be observed now with large telescopes. Professors Hussey and Perrine at Lick Observatory had followed the comet up to Oct. 29, according to a private letter from one of the observers dated Nov. 6. The ephemeris computed from elliptic elements determined by these gentlemen was then in error only about 10ˢ in right ascension and ½′ in declination. Professor Hussey is making a redetermination of the orbit. The following elements are the best at hand:

ELEMENTS OF COMET *d* 1896.

Computer	Hussey and Perrine		Perrotin and Giacobini	
Epoch	Sept. 5.5 Gr. M. T.		Sept. 15.5 Berlin M. T.	
	° ′ ″		° ′ ″	
M	354 43 37		353 33 11	
ω	191 44 13	1896.0	193 34 34	1896.0
Ω	139 5 28		140 44 13	
i	11 35 18		11 20 32	
$\log e$	9.82189		9.76753	
$\log a$	0.64636		0.54411	
μ	380″.60		541″.80	
Period	9.323 years		6.549 years.	

It will appear that there is yet considerable uncertainty as to the comet's period. Professor Hussey states that the observations upon which the above elements are based are satisfied by a remarkably different set of elements, with a period of only 510 days, but that these last do not represent the later observations.

Elements and Ephemeris of Comet *f* 1896.—Computed by F. H. Seares from Lick observations of Nov. 2, 3 and 4, and telegraphed from University of California.

$T = 1897$ Jan. 23.64

$\omega = 139\ 0$
$\Omega = 79\ 53$ } M. Eq. 1896
$i = 145\ 55$
$q = 1.4870$

1896	Ephemeris for Greenwich Midnight. α	δ	Brightness
	h m s	° ′	
Nov. 11	20 8 28	+18 23	0.92
15	20 4 16	15 43	
19	20 0 56	13 17	
23	19 58 20	+11 4	0.81

—*The Astronomical Journal*—Supplement to No. 388.

GENERAL NOTES.

Dr. Herman S. Davis, of Columbia University, has returned from a visit to several European Observatories. While abroad he consulted Prof. Auwers and other eminent astronomers regarding a new reduction of all Piazzi's star observations; and after examining such manuscripts as exist arrangements were made whereby this important undertaking will be begun at once in co-operation with Prof. Porro, Director of the Royal Observatory of Turin. Dr. Davis will be assisted in this work by Mrs. Davis, who for the past two years has been employed as computor at Columbia University Observatory.

Rotation of Venus.—We are sure our readers will find much interest in the first article of this number. The rotation period of Venus is observationally most difficult, as will be seen, by those who are not experienced in the use of large telescopes, by reading the paragraphs citing the work of other skilled astronomers, as well as the other parts of the article giving in detail the interesting work of Mr. Lowell and his assistants. So far as we know from the published work of Schiaparelli, he has not been able to determine with certainty the rotation time of Venus. As Young puts it, his observations are sufficient to show that the period of Schroeter ($23^h\ 21^m$) is very likely wrong and that the planet probably rotates like Mercury, only once in an orbital revolution, keeping the same face always towards the Sun. It is then hardly fair to Mr. Lowell to claim as some amateur astronomers are doing that his recent observations confirm the conclusions of Schiaparelli.

o **Ceti.**—The maxima of the variable star *o* Ceti having occurred later in recent years than the dates assigned in accordance with previous observation, it is probable that the minima have been correspondingly retarded On this asumption I anticipated the dim phase in the beginning of September last, unfavorable atmospheric conditions hindered a satisfactory observation until the midnight of Sept. 25th when the variable was near the meridian. It was distinctly brighter than the companion of 10th magnitude, perhaps one magnitude brighter but not more. In the moonlight they seemed exactly alike in tint. As it has been slowly but steadily increasing in size being now of the 7th magnitude it is probable that the minimum was some weeks past on the date named. ROSE O'HALLORAN.

San Francisco, Nov. 11th, 1896.

The Great Yerkes Lens.—We have noticed in some prominent papers the statement that the Yerkes lens, after two and one-half years of hard work by

Alvan Clark of Cambridgeport, Mass., is at last completed, and is now awaiting orders for its removal to the new Observatory of the Chicago University, situated at Williams Bay, Lake Geneva, Wisconsin. It is also said in some newspaper notices that "The cost of the glass discs in Paris was $40,000 and the entire cost of the lens is estimated to have been $100,000. For its journey west it will be wrapped in flannel and imbedded in curled hair in a box mounted on springs, and packed with excelsior in a larger box. It will ride in the center of a parlor car and be accompanied by four men." Parts of this description of the methods of carrying the Yerkes objective to Chicago, were so amusing to us that we asked one of the officials of the new Observatory about the arrangements for transportation and any other facts that he might furnish for publication. The following facts are given:

"So far as I know the clear aperture of the objective is not much over 40-inches. Its weight is about 500 pounds and the cell weighs as much more. The focal-length is about 61 feet. The cost of the rough glass was about $20,000 and the finished objective cost about $66,000 (including the glass). The objective will soon be brought to Chicago, but the details of transportation have not yet been arranged (Nov. 6, '96). There is no reasan to believe that four men will be needed to accompany it."

Acknowledgement of Solutions of Problems in Previous Numbers—The delay in acknowledging solutions was due to the temporary loss of the MSS in my library. The problems are resumed in this number and we hope our astronomical friends will respond by forwarding solutions at as early a date as practicable. The problems proposed present no difficulty to students and amateurs possessing a moderate acquaintance with the elementary branches of mathematics. Acknowledgments will be given in our next paper on eclipses.

Mr. Orrin E Harmon of Chehalis, Wash., solved problems 8, 9, 10, 11, 12, 13 in part, 14, 15, 16, 17, 18 in part, 19, 20 and 21. Some of Mr. Harmon's solutions were original and quite elaborate.

Mr. Thomas Lindsay of Toronto, Ont., solved problems 9, 10, 11, 12, 14, 16 in part, 17, 19. J. MORRISON.

Brilliant Solar Protuberance.—While making my usual solar observation on October 23d, 1896 I observed an eruptive prominence which in point of brilliancy surpassed any that I have hitherto seen.

After having completed the visual observation of the spots and faculæ, I attached the spectroscope and turning to the east limb observed at 11:55 A. M., central time, at position angle 110° approximately, an intensely brilliant protuberance with some lighter filaments near, in the Hα line; was not large but appeared to be in a violently agitated state. With a narrow slit the Hα line had a winged appearance, it was so exceedingly bright that it could be easily seen with a very widely-opened slit; the 2d order of a 14,438 lines Rowland grating was used and the brilliant scarlet flame appearing in the same field of view with a like appearance in blue, in the Hβ line of the overlapping spectrum of the 3d order was quite interesting. Upon rotating the grating I noticed that the appearance was about the same in the D_3, Hδ and Hγ lines, no reversals of other lines could be detected in the rather hurried observation and I was obliged to cease observing at 12:10 P. M. Leaving the spectroscope attached and undisturbed I returned to it again at 1:40 P. M., but the phenomenon had entirely disappeared, only a few faint low filaments remaining. I carefully examined the region within the

disc at the place of disturbance without finding any displacement or reversals of lines, except a faint dark shading caused by the umbra of a spot which was just on the edge of the disc at the point where the eruption had occurred—a mere trace of light separating it from the limb. This spot I had not noticed a couple of hours before, as it was probably precisely on the edge of the limb.

Could it be possible that the disturbance originated below the spot and that the opening of the umbra was the outlet of the ejected matter?

That the eruption occurred within or very near the spot seems certain, as no disturbance was evident in the faculæ surrounding and following the spot at any subsequent observation.

It will be of interest to know whether this phenomenon has been more completely and minutely examined by other observers.

A fine group of prominences was observed on the Sun's western limb on October 25th, 1896, the larger one having a feather-like appearance composed of very delicately formed filaments which remained more or less quiescent during the time of observation from 1:00 to 2:30 P. M. Several transits across the slit occupied 14ˢ from the base to the top of the prominence, equivalent to an absolute height of 90,000 miles. DAVID E. HADDEN.

Alta, Iowa, Oct. 26th, 1896.

Galileo's Observations of Saturn's Rings.—In the August number of POPULAR ASTRONOMY, the editor states that some time ago he had called our attention to a communication from Professor Young which communication has since been published in the same publication. The editor's letter we have never received and hence the lack of reply was not a discourtesy on our part. Our attention was called only a few days ago to Professor Young's criticism of our paper.

In our paper we wished to bring out that Galileo's letter to Velser has been unfairly treated, the extract stopping at a place that gave a wrong impression as to the state of Galileo's mind. We further wished to emphasize the fact that Galileo made observations of Saturn subsequent to 1612; and these subsequent observations, we think, did add to our knowledge of Saturn, furnishing as they did a b tter drawing than h ud been given previously.

In Young's General Astronomy is the following passage:

"Galileo, in 1610, saw with his little telescope that the planet appeared to have something attached to it on each side, and he announced the discovery that the 'outermost planet is triple'—'ultimam planetam tergeminam observavi.' Not long afterwards, the rings were edgewise to the Earth so that they became invisible to him; and in his perplexity he inquired 'whether Saturn had devoured his children, according to the legend.'"

We feel that our criticism is justified. In the passage just quoted, there is certainly no explicit statement that Galileo did nothing further with respect to Saturn but we think a reader of the passage would infer this—just as we did.

E. A. P.

Attention is called to an error in Mr. Burnham's description of a new ellipsograph in the October number, page 182, in reference to the value of the longer axis on the divided scales of the instrument. It should have been stated that the semi-major axis $= CH + (DH - DP) = 2\,CH - DP$.

Erratum.—On page 275, November number for N Scorpii read R Scorpii.

The Leonids at Lincoln, Neb.—A few pioneer Leonids were observed here this morning, between one and two o'clock. Their radiant point as approximately determined was $\delta = 22°$; R. A. $9^h\ 46^m$. They were faint, rapid, with short paths. G. D SWAZEY.